SAFETY ANALYSIS REPORT

of TPL-92Y-450K Package for Tritium Transport

JAPAN ATOMIC ENERGY RESEARCH INSTITUTE

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(MITSUBISHI HEAVY IND. LTD)

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Section (I) Description of Package for Radioactive Material Transport

Section (I)-A Purpose and Conditions

(I) Description of the Package for Radioactive Material Transport

A. Purpose and Condition

(1) Purpose for use of the package

The purpose of this package is to transport the Tritium (25 g in the maximum) produced and refined in foreign countries, as a hydride absorbed in a getter (ZrCo), to the Tritium Process Laboratory of the Japan Atomic Energy Research Institute.

Conceptual figure of the package is shown in Fig. (I)-A.1.

(2) Nomination of the type of package:

TPL-92Y-450K

(3) Type of package: BU-type package IAEA safety series No. 6 (1985)

(4) Limit of number of units: None

(5) Limit array of units: None

(6) Transport Index: 0

(7) Maximum weight of package: 450 kg approx.

(including 23 kg approx. of the material to be stored)

(8) Outer dimension of package

(a) Outer diameter: 620 mm approx.

(b) Height: 1,200 mm approx.

(9) Main materials used for the packaging

(a) Protective container:

Stainless steel + Balsa wood + Copper (Inner fin)

(b) Primary container body: Stainless steel

(c) Spacer: Aluminum

(10) Specification of radioactive material to be stored in the package

(a) Kind of radioactive material

Tritium (Form of ZrCo (Zirconium • Cobalt Alloy) hydride)

(b) Weight of radioactive isotope: 25 g in the maximum

Weight of tritium compound		: approx. 775 g
Contents	ZrCo	: approx. 750 g
	Tritium	: 25 g in the max.

(c) Quantity of radioactivity: max. 9.25 PBq/package

(d) Heat generated: 25 W in the max. (The decay heat generated by Tritium is 8W but the heat rejection capability for the package has been specified as 25W.)

(e) Capsule

(i) Maximum outer diameter: 220 mm approx.

(ii) Maximum height: 700 mm approx.

(iii) Weight: approx. 23 kg (inclusive of ZrCo)

(iv) Material: Stainless steel

(11) Method of transportation:

Land transport by trailer, sea transport by vessel or air transport by freighter.

(12) Cooling method: Natural cooling

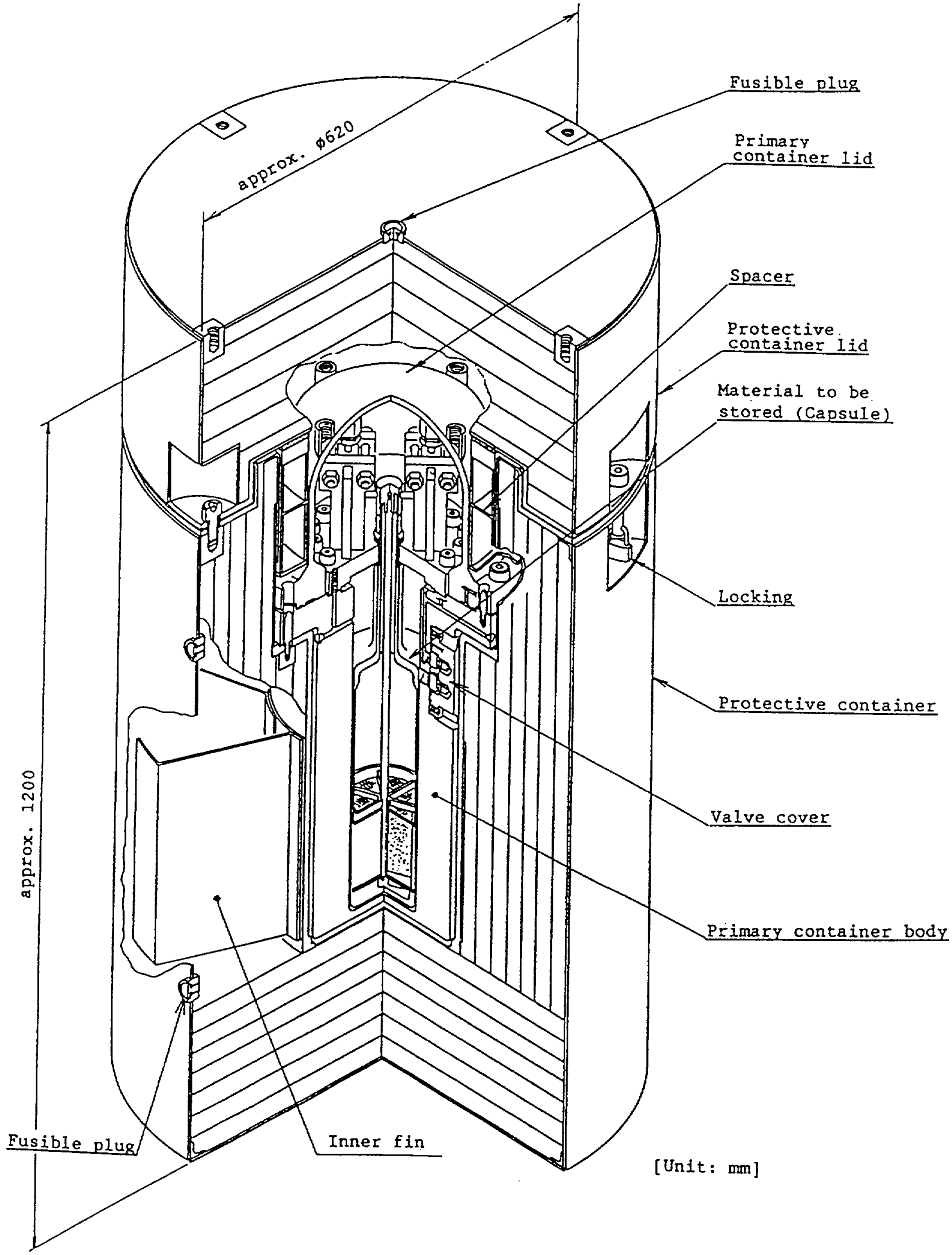


Fig. (I)-A.1 Sectional view of the package

Section (I)-B Kind of Package

(I)-B Kind of Package

(1) Kind in terms of package type

The package is categorized as Type B, according to the reason that radioactivity of the radioactive isotopes to be contained in this packaging exceeds the value, A_2.

(2) Package for fissile material transport

This article does not apply since this packaging never contains any kind of fissile materials.

This package is defined as "BU-type package," since the main purpose is to transport Tritium from overseas to Japan.

Section (I)-C Packaging

(I)-C Packaging

This packaging consists of a primary container, a protective container and a spacer.

C.1 Structure of Packaging

The packaging is a cylindrical shape of 620 mm in outer diameter and 1,200 mm in height. The primary container, which is the containment boundary of the package, is contained in the protective container possessing the function of a shock absorber. The primary container consists of a primary container body and a primary container lid. The protective container consists of a protective container body and a protective container lid. During transport, an aluminum spacer is installed into the space between the primary container and the protective container.

General assembly of the packaging is shown in Fig. (I)-C.1. The state of transport is shown in Fig. (I)-C.2. The containment boundary of the packaging is shown in Fig. (I)-C.3.

The structure of the packaging is roughly described as follows.

(1) Primary container body (Ref. Fig. (I)-C.4)

The primary container body is made of stainless steel, having the outer diameter of 240 mm and the height of 502 mm. The top of it is a flange structure having an outer diameter of 360 mm, which comprises the containment boundary by means of being fastened with a primary container lid. There are __ bolt holes through which the capsule is fixed by bolts to the inside of the top-surface and there are 16 bolt holes to fasten the primary container lid at the outside of the top surface.

Helium is filled (initial filling pressure: 0.030 MPa • G) in the primary container during transport in order to dissipate the decay heat from the capsule which is the material to be stored of the package, and to prevent the possibility of ZrCo's degradation by contacting it with air by keeping the helium pressure higher than the ambient pressure.

On the hull part, there are two valves for the purpose of gas purge and ventilation inside the primary container.

During transport, the valves are covered with a valve cover. Since a valve cover becomes containment boundary, two O-rings are installed in order to accommodate the containment test which is performed by using a testing hole provided in the space between the two O-rings.

(2) Primary container lid (Ref. Fig. (I)-C.5)

The primary container lid is made of stainless steel and is a structure welded a cap on a flange, having an outer diameter of 360 mm and a height of

248 mm.

The lid is to be fastened with the primary container body by 16 of tie-down bolts. There are ____ bosses for eye-bolt installation on the top of it for the purpose of lifting the primary container. The surface of flange is designed to maintain the containment of the primary container by a metal O-ring and an elastomer O-ring installed outside of it, in order to accommodate the containment test by using a testing hole provided in the space between the two O-rings.

(3) Protective container body (Ref. Fig. (I)-C.6)

The protective container body is of double wall cylindrical shape having an outer diameter of 620 mm and a height of 971 mm. It is a weld construction using 4 mm stainless steel for external plate (both hull and bottom) and 10 mm stainless steel for internal plate. In the space formed between the external and the internal plate, balsa wood is filled to absorb the energy imposed by drop impact. In order to dissipate the decay heat by Tritium, it is required to provide a heat removal path, so that there are 8 of copper inner fins on the hull part, connecting the external and internal side plates, and on the outer side there are 4 fusible plugs provided thereon in order to prevent internal pressure from increasing by the vapor and the gas generated from balsa-wood in fire accident.

(4) Protective container lid (Ref. Fig. (I)-C.7)

The protective container lid comprises welded structure of double layer cylindrical shape having an outer diameter of 620 mm and a height of 280 mm approximately, the external and internal sides of which are made of stainless steel (both the hull and upper plate).

Within the cylinder, balsa wood is filled as a shock absorber.

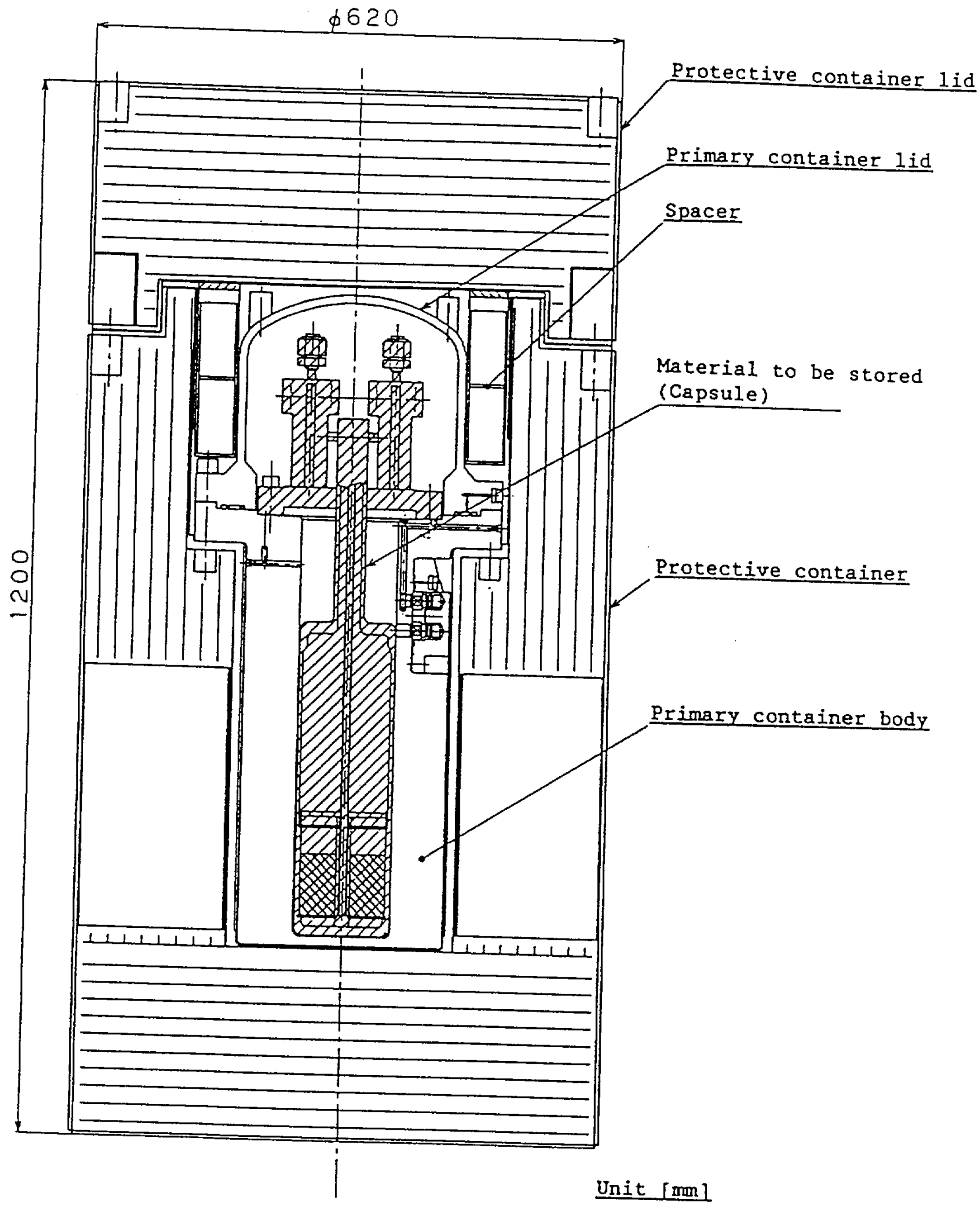
The fastening of protective container and the lid is made with 8 bolts with an rubber packing for maintaining water tightness.

On the top of the lid, _ portion for eye bolt installation are established so as to perform the lifting of the package.

As a preventive measure against the unauthorized opening of the package during transport, a locking device is provided through a penetration provided on the fastening surface between the protective container body and the lid.

(5) Spacer (Ref. Fig. (I)-C.8)

In the space between the primary container lid and protective container, spacer made of aluminum is inserted so as to fix the primary container. There are ___ screws for eyebolts to insert and remove it from the space.



Unit [mm]

Fig. (I)-C.1 General assembly of the packaging

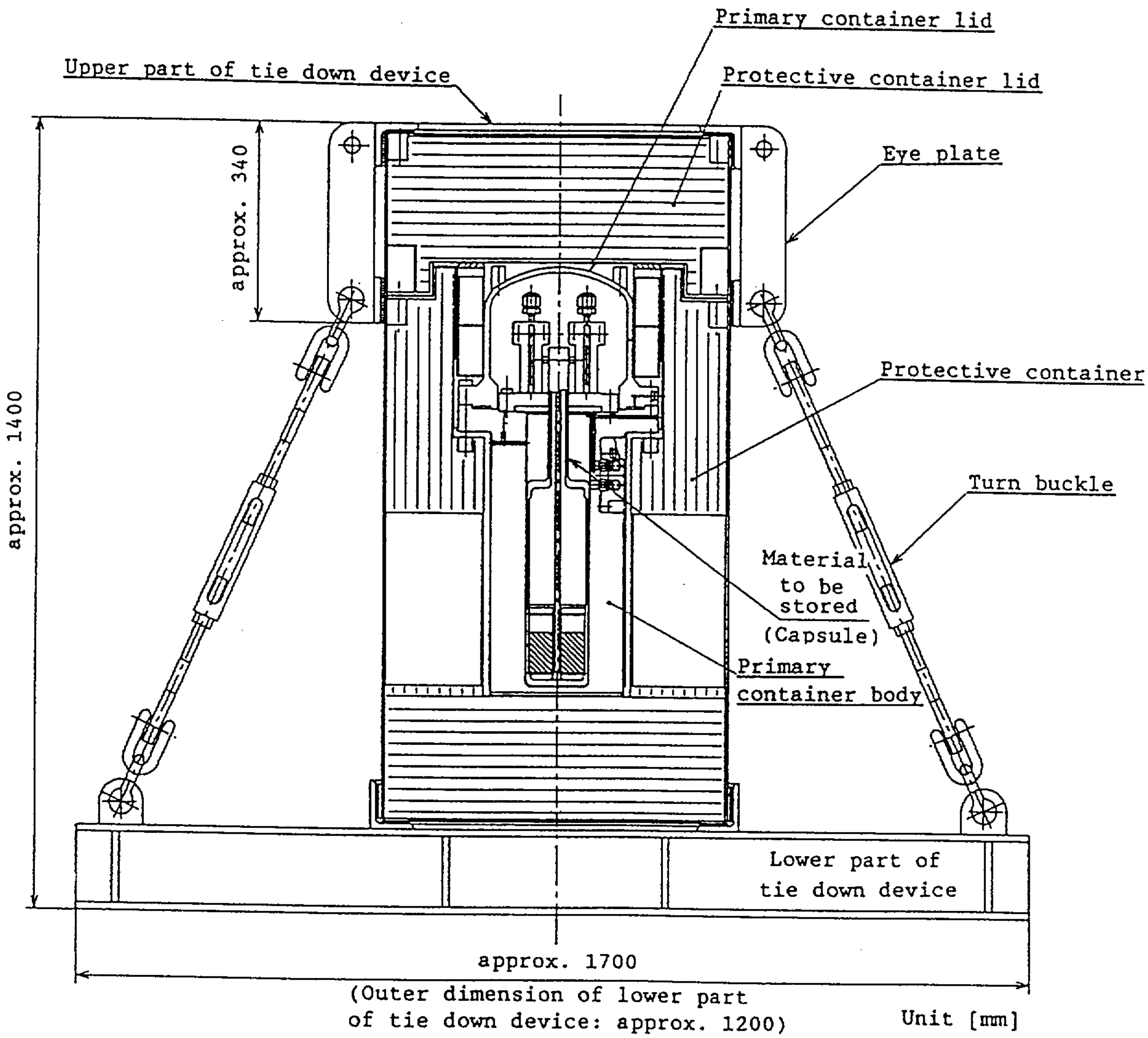


Fig. (I)-C.2 State of transport

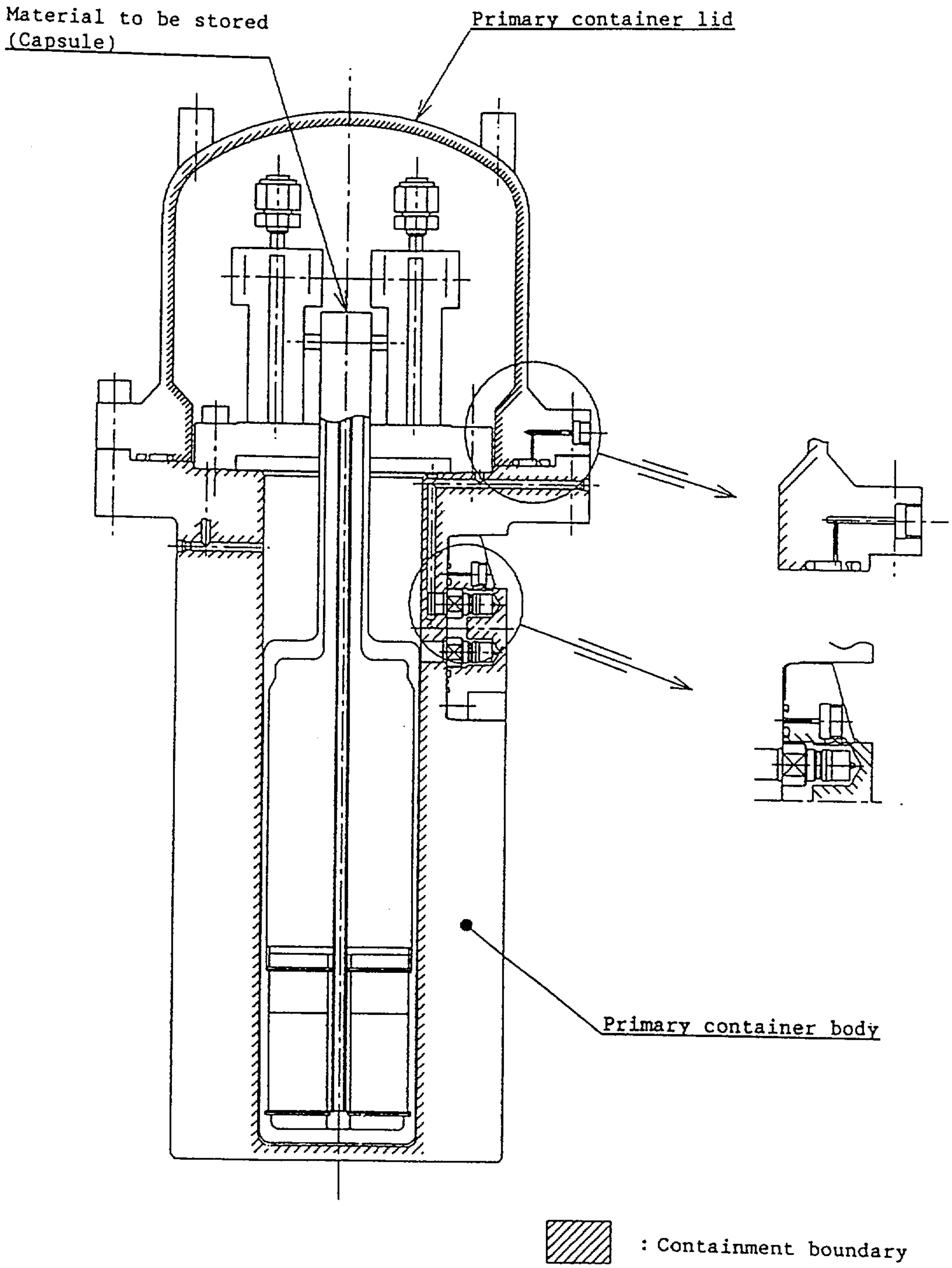


Fig. (I)-C.3 Containment boundary of the packaging

PROPRIETARY

Fig. (I)-C.4 Primary container body

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Fig. (I)-C.5 Primary container lid

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Fig. (I)-C.6 Protective container body

PROPRIETARY

Fig. (I)-C.7 Protective container lid

PROPRIETARY

Fig. (I)-C.8 Spacer

C.2 Materials Employed in Packaging

Materials employed in packaging are shown in Table (I)-C.1.

C.3 Dimension of Packaging

Dimensions of packaging are shown in Table (I)-C.2.

C.4 Weight of Packaging

Weight of packaging is shown in Table (I)-C.3.

Table (I)-C.1 Construction Material of Packaging (1/2)

Composing part	Material	Number	Remarks
1. Primary container			
1.1 Primary container body			
(1) Primary container body	Stainless steel	1	
(2) Valve cover	Stainless steel	1	
1.2 Primary container lid			
(1) Flange part	Stainless steel	1	
(2) Cap part	Stainless steel	1	
1.3 Others			
(1) Capsule flange fixing bolt (hexagon socket head cap screw)	Stainless steel	—	M12
(2) Valve cover tie-down bolt (hexagon socket head cap screw)	Stainless steel	—	—
(3) Primary container lid tie-down bolt (hexagon socket head cap screw)	Stainless steel	16	—
(4) Eye bolt fixing boss	Stainless steel	—	
(5) Metal O-ring	Inconel covered with aluminum	1 unit	
(6) Elastomer O-ring	Silicon rubber	1 unit	
(7) Valve	Stainless steel etc.	2	

Table (I)-C.1 Construction Material of Packaging (2/2)

Composing part	Material	Number	Remarks
2. Protective container			
2.1 Protective container body			
(1) External plate	Stainless steel	1 unit	
(2) Internal plate	Stainless steel	1 unit	
(3) Flange	Stainless steel	1	
(4) External bottom plate	Stainless steel	1	
(5) Internal bottom plate	Stainless steel	1	
(6) Shock absorber	Balsa wood	1 unit	
2.2 Protective container lid			
(1) External plate	Stainless steel	1 unit	
(2) Internal plate	Stainless steel	1 unit	
(3) Flange	Stainless steel	1	
(4) Shock absorber	Balsa wood	1 unit	
2.3 Others			
(1) Protective container lid tie-down bolt (hexagon socket head cap screw)	Stainless steel	8	—
(2) Eye bolt fixing seat	Stainless steel	1 unit	
(3) Fusible plug	Solder + Stainless steel	1 unit	
(4) Inner fin	Copper	1 unit	
(5) Packing	Ethylene propylene rubber	1	
3. Spacer			
(1) Spacer body	Aluminum	1 unit	
(2) Cushion rubber	Silicon rubber	1 unit	

Table (I)-C.2 Dimensions of Each Part of Packaging

Composing part	Position	Nominal dim. (mm)	Remarks
1. Primary container			
1.1 Primary container body	Hull part outer diameter	240	
	Flange part outer diameter	360	
	Inner diameter	114	
	Height	502	
1.2 Primary container lid	Flange part outer diameter	360	
	Cap part outer diameter	250A	
	Height	248	
	Bolt size	—	
2. Protective container			
2.1 Protective container body	Outer diameter	620	
	Inner diameter	246	
	Height	971	
2.2 Protective container lid	Outer diameter	620	
	Inner diameter	451	
	Height	280	
	Bolt size	—	
3. Spacer			
3.1 Spacer body	Outer diameter	365	
	Inner diameter	270	
	Height	190	
3.2 Cushion rubber	Thickness	8	

Table (I)-C.3 Weight of Packaging

No.	Name	Weight (kg)
1	Primary container body	160
2	Primary container lid	35
3	Protective container body	172
4	Protective container lid	53
5	Spacer	7
Packaging maximum weight (1+2+3+4+5)		427

The maximum weight of the package, inclusive of the weight of material to be stored (the capsule)# is 450 kg.
Where (#): The weight of the capsule: about 23 kg (Refer to Table (I)-D.2.)

Section (I)-D Material to be Stored (Radioactive Content)

(I)-D Material to be Stored

The content of this packaging is the capsule which contains getter (ZrCo) where Tritium, in a chemical state of metallic hydrogen compound, is absorbed.

This capsule is filled with approximately 750 g of ZrCo which is capable of absorbing maximum of 25 g of Tritium.

D.1 Structure of the Capsule

The capsule is composed mainly of stainless steel, the structure of which is shown in Fig. (I)-D.1.

During transport, the capsule is to be fixed to the primary container body by means of __ fixing holes provided on the capsule flange.

There are two lines on the upper part of the capsule. Each line has highly leak-tight valve and separating joint in order to perform the absorption and discharge of tritium gas, and the said valve and joint are fixed on the capsule flange with supports.

The capsule body, which is filled with ZrCo where Tritium gas is absorbed, has closed structure.

D.2 Major Dimensions of the Content

The major dimensions of the content (the capsule) are as shown in Table (I)-D.1:

Table (I)-D.1 Major Dimensions of the Content (Capsule)

Name of major part	Location	Nominal dimension (mm)	Remarks
1. Capsule flange	Outer diameter	216	Total height: about 700 mm in full assembly
	Thickness	32	
	Fixing bolt	M12	
2. Capsule body	Outer diameter	112	
	Inner diameter	104	
	Height	590	

D.3 Specification of the Content

The specification of the content (capsule) is given in Table (I)-D.2:

Table (I)-D.2 Specification of the Content (Capsule)

Items	Contents	Remarks
1. Kind of radioactive isotope to be stored.	Tritium	Tritium compound of ZrCo
2. Maximum weight of radio-active isotope to be stored.	25 g	Tritium compound : 775 g ZrCo : 750 g Tritium : 25 g
3. Max. radioactivity	9.25PBq	
4. Max. heat generation	25 W*	
5. Weight of capsule	about 23 kg	
6. Materials of the content	Stainless steel & others	

* Safety factor of about 3-times is taken into consideration.

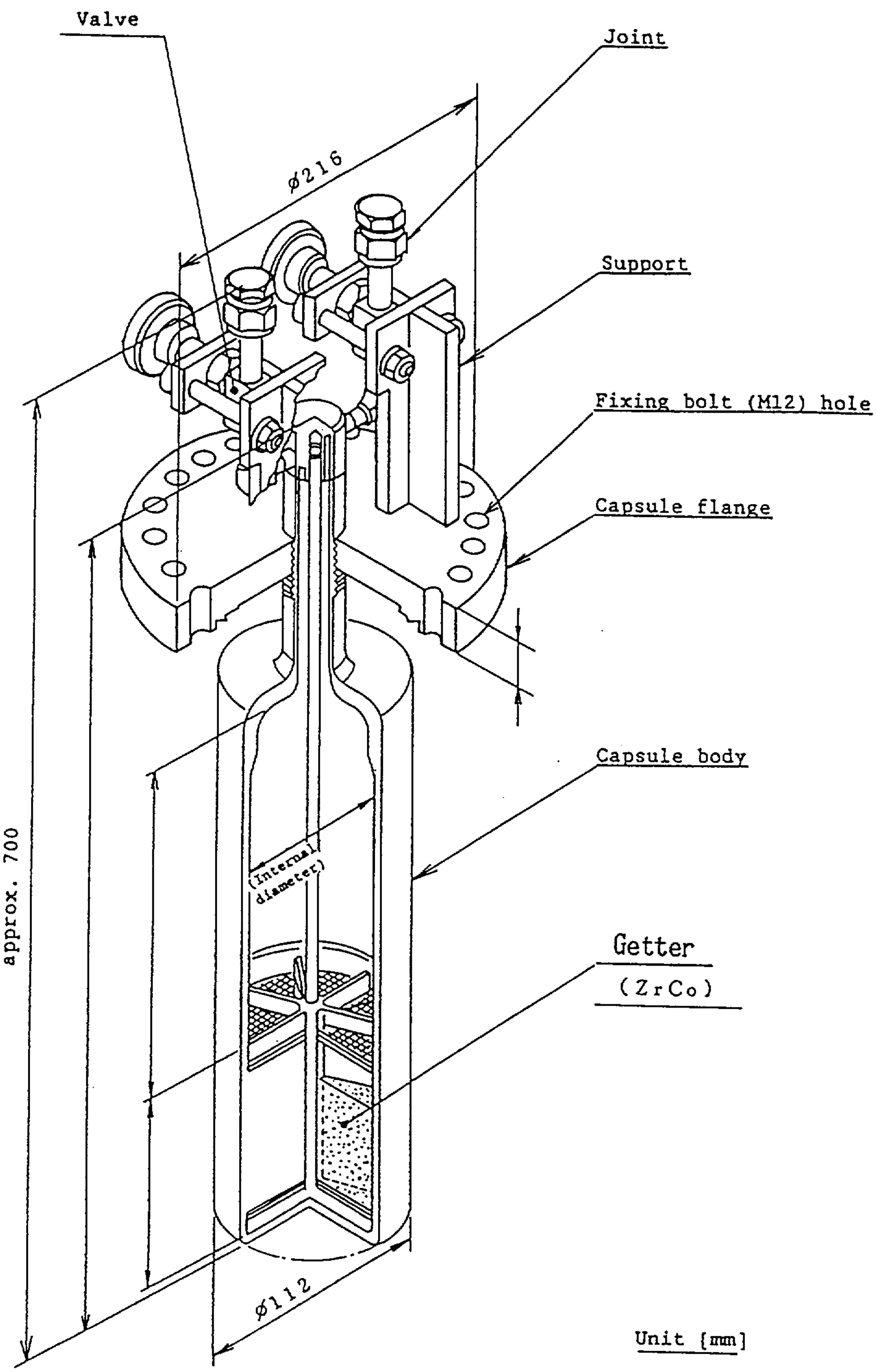

Fig. (I)-D.1 Sectional view of the content (capsule)

II Safety Analysis of the Package

(II) Safety Analysis of the Package

In this section, an evaluation is made that this package satisfies the design requirements for BU-type package, i.e., the regulations stipulated by the Ordinance issued by Japanese Competent Authority based on IAEA Regulation for the Safe Transport of Radioactive Material.

(1) Criteria regarding BU-type package

(a) Routine conditions of BU-type package

(i) It shall enable handling with ease and safety.

(ii) The package shall be capable of withstanding the effects of any acceleration, vibration or vibration resonance which may arise under conditions likely to be encountered in routine transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole. In particular, nuts, bolts, and other securing devices shall be so designed as to prevent them from becoming loose or being released unintentionally, even after repeated use.

(iii) As far as practicable, the packaging shall be so designed and finished that the external surfaces are free from protruding features and can be easily decontaminated.

(iv) The materials of the packaging and any components or structures shall be physically and chemically compatible with each other and with the radioactive contents. Account shall be taken of their behaviour under irradiation.

(v) All valves through which the radioactive contents could otherwise escape shall be protected against unauthorized operation.

(vi) The smallest overall external dimension of the package shall not be less than 10 cm.

(vii) The outside of the package shall incorporate a feature such as a seal, which is not readily breakable and which, while intact, will be evidence that it has not been opened.

(viii) The design of the package shall take into account temperatures ranging from -40° to 70°C for the components of the packaging. Special attention shall be given to freezing temperatures for liquid contents and to the potential degradation of packaging materials within the given temperature range.

(ix) The containment system shall retain its radioactive contents under a reduction of ambient pressure to 25 kPa (0.25 kgf/cm^2).

(x) The 1-cm dose rate should never exceed the limit of 2 mSv/hr at the container surface.

(xi) The 1-cm dose rate at a distance of 1 m from the container surface must never exceed 100 μSv/hr.

(xii) The density of radioactive isotope at the surface must never exceed the following limits:

α radioactive material : 0.4 Bq/cm^2

βγ radioactive material: 4 Bq/cm^2

(xiii) No objects or matters should be contained with the packaging except those documents or other items necessary for utilization of the radioactive isotopes, etc.

(b) Normal conditions of transport for BU-type package

The BU-type package shall satisfy the requirements listed in item (II) below, when exposed to the normal conditions of transport as described in Item (I) which follows:

(I) Normal conditions of transport

(i) The package shall be subjected to 12-hour loading of radiation heat as described below each day in an environment of 38°C for one week.

Category of surface shape and position		Insolation heat (w/m^2)
Plane exposed to horizontal transport	Base plate	None
	Other	800
Plane other than the above		200
Bending surface		400

(ii) The package shall be exposed to water spray for one hour equivalent to rain fall of 50 mm/hr.

(iii) The specimen shall be dropped onto the target so as to suffer maximum damage in respect of the safety features to be tested.

1) The height of drop measured from the lowest point of the specimen to the upper surface of the target shall not less than the distance specified in the followings for the applicable mass.

- A height of 1.2 m (mass less than 5,000 kg)
- A height of 0.9 m (mass greater than 5,000 kg and less than 10,000 kg)
- A height of 0.6 m (mass greater than 10,000 kg and less than 15,000 kg)
- A height of 0.3 m (mass more than 15,000 kg)

2) When the package dropped is made from fibre plate and weights less than 100 kg, it will be dropped from a 0.3 m height so as to incur maximum damage on each of a quarter of the area on both ends of the package.

3) Following the step indicated in article 1), the package will be subjected to a weight equal to whichever is larger 5 times the weight used in the previous test, or the weight equivalent to 13 kPa multiplied by the area of vertical projection for 24 hours.

4) Following step 3), a steel bar with a weight of 6 kg and 3.2 cm in diameter will be dropped from a 1-m height.

(II) Requirements

(i) The 1-cm dose-rate at the surface shall neither increase significantly, nor exceed the prescribed limit of 2 mSv/hr.

(ii) Leakage of radioactive isotope per hour shall never exceed $A_2 \times 10^{-6}$.

(iii) The surface temperature shall never exceed 50°C in shade. In the case of transport as an exclusive use, the temperature limit will not exceed 85°C at the surface, (or at the perimeter of access-preventive fencing, if used).

(iv) The density of radioactive isotope at the surface shall never exceed the surface density limit (1)(a)(v).

(c) Accident conditions for transport of BU-type package

When the package is to be sequentially subjected to the accident conditions of transport indicated in Item (I) below, the requirements cited in Item (II) shall be satisfied.

(I) Accident conditions of transport

(i) Let the package drop from a height of 9 m.

(ii) Let it drop from a height of 1-m onto a mild steel bar having a diameter of 15 cm and length of 20 cm.

(iii) Place the package in an environmental temperature of 38°C, and then in an environment of 800°C for 30 minutes. While loading solar radiation, let the package be cooled naturally.

(iv) Immerse the package in water at a depth of 15 m for 8 hours.

(II) Requirements

(i) The 1-cm dose-rate equivalent at 1 m from the surface shall never exceed 10 mSv/hr.

(ii) Leakage per week of the radioactive isotope shall never exceed A_2.

(d) Technical criteria regarding BU-type package

(i) It must be able to endure temperatures within an ambient temperature range of -40°C to 38°C without cracking, breaching or otherwise being damaged.

(ii) Construction must be arranged that filtration of internal gases and cooling of radioactive isotopes inside the package will be available without incorporating any filter or mechanical cooling device.

(iii) The annual maximum operating pressure (i.e., the highest pressure of gasses in one year under the conditions of foreseeable ambient temperatures during transport while exposed to direct solar radiation) shall not exceed 700 kPa•G.

(e) Additional requirements for packages for transport by air.

(i) The packages shall be constructed such that the containment boundary of the package shall be able to maintain its integrity and containment capability in an environment ranging in ambient temperature from -40°C to 55°C.

Section (II)-A Structural Analysis

(II)-A Structural Analysis

In the structural analysis, the deformation, damage, etc, which will be incurred on the package under the routine condition, normal, and accident conditions of transport, are to be analyzed and evaluated, then, the results shall be reflected as the thermal and containment analysis base.

A.1 Design criteria

It shall be verified for the package to comply with the criteria under each of the testing conditions regulated in IAEA regulation (1985 ed.) in order to obtain the license as Type BU package.

(a) Design criteria

The design criteria is as shown in Table(II)-A.1.

The criteria evaluation is defined on the basis of the comparison between the operation states described in ASME, Sec III subsec NB and the conditions described in IAEA transport regulation.

As for the routine and normal conditions of transport, Level A Service Limit and as for accident conditions of transport, Level D Service Limit are applied respectively, namely, the specific portions where the containment maintenance is required, (i.e., the primary container) shall not be allowed with any failure under the accident conditions of transport.

The primary container lid fastening bolt which will affect seriously the containment charactaristics by their plastic deformation shall not exceed the yield stress in accident conditions of transport.

And further, the criteria applied in case of penetration test shall be so specified as to be the puncture resistive strength maintained in the vicinity of the location where the collision takes place.

As for the lifting and tie down devices, the design criteria are given as the design yield stress.

Sm : Design stress intensity

Sy : Design yield strength

Su : Design tensile strength

(b) Load combination

In performing structural evaluation of the portions of the package, the load combination shown in Table(II)-A.2 shall be considered.

(c) Margin of safety(MS)

As for the analysis results, which have quantitative criteria, the evaluation shall be made by means of "Margin of safety" defined as follows.

$$\text{Margin of safety(MS)} = \frac{\text{analytical criteria}}{\text{analysis result}} - 1$$

Therefore, if MS is larger than 0(zero), it shall be acceptable.

As for the others, the criteria and other requirements are set forth where applicable.

Table(II)-A.1 Structural analysis criteria

Pm : Primary general membrane stress
PL : Primary local membrane stress
Pb : Primary bending stress
Q : Secondary stress
F : Peak stress
DF : Fatigue accumulation factor

Requirement	Condition	Item of Analysis	Point of evaluation \ Stress category	Primary stress intensity: Pm(PL)	Primary stress intensity: PL+Pb	Primary + Secondary Stress intensity: PL+Pb+Q	Primary + Secondary Peak intensity: PL+Pb+Q+F
BU Type package	Routine condition	Lifting device	Portion of eye bolt installation	<Sy	<Sy	–	–
		Tiedown device	Eye plate	<Sy	<Sy	–	–
		Pressure	Package	Endurable to the atmospheric pressure variation.			
		Vibration	Package	Endurable to the vibration incurred during the transportation.			
	Normal conditions of transport	Thermal test	Capsule	<Sm	<1.5Sm	<3Sm	–
			Primary container body				Fatigue evaluation (Df<1)
			Primary container lid				
			Primary container lid tie down bolt	<Sy/1.5	<Sy	<Sy	
		Water spray	Package	Endurable to the water jet.			
		Free drop (1.2m drop)	Capsule	<Sm	<1.5Sm	<3Sm	–
			Primary container body				Fatigue evaluation (DF<1)
			Primary container lid				
			Primary container lid tie down bolt	<Sy/1.5	<Sy	<Sy	
		Stacking test	Protective Container	<Sy	<Sy	–	–
		Penetration test	Protective Container	Puncture resistive strength.			
	Accident conditions of transport	Drop test I (9m drop)	Capsule	<Su/1.5	<Su	–	–
			Primary container body				
			Primary container lid				
			Primary container lid tie down bolt	<Sy/1.5	<Sy		
		Drop test II (1m drop onto mild steel bar)	In the vicinity of collision area on the protective container	Puncture resistive strength.			
		Thermal test	Capsule	<2/3Su	<Su	–	–
			Primary container body				
			Primary container lid				
			Primary container lid tie down bolt	<Sy/1.5	<Sy	–	–
		15m Immersion	Primary container body	<2/3Su	<Su	–	–
			Primary container lid				

* Since it is the contents, hereafter it is referred to as capsule.

Table(II)-A.2 Design load combination

Requirement	Condition	Item of Analysis	Kind of load / Point of evaluation	Weight	Pressure	Thermal expansion	Others
BU Type package	Routine condition	Lifting device	Portion of eye bolt installation	△	–	–	–
		Tiedown device	Eye plate	△	–	–	–
		Pressure	Package	–	△	–	–
		Vibration	Package	–	–	–	△ (Vibration associated with transportation)
	Normal conditions of transport	Thermal test	Capsule	–	△	–	–
			Primary container body	–	○	○	–
			Primary container lid	–	△	–	–
			Primary container lid tie down bolt	–	○	○	○(Initial fastening force)
		Water spray	Package	–	–	–	△(Water spray)
		Free drop (1.2m drop)	Capsule	○	○	–	–
			Primary container body	○	○	○	–
			Primary container lid	○	○	–	–
			Primary container lid tie down bolt	○	○	○	○(Initial fastening force)
		Stacking test	Protective Container	△	–	–	–
		Penetration test	Protective Container	–	–	–	△ (Dropping of a 6kg mild steel-rod)
	Accident conditions of transport	Drop test I (9m drop)	Capsule	○	○	–	–
			Primary container body	○	○	–	–
			Primary container lid	○	○	–	–
			Primary contianer lid tie down bolt	○	○	–	○(Initial fastening force)
		Drop test II (1m drop onto mild steel bar)	In the vicinity of shocked area on the protective container	△ Package weight × 1m height	–	–	–
		Thermal test	Capsule	–	△	–	–
			Primary contianer body	–	△	–	–
			Primary contianer lid	–	△	–	–
			Primary container lid tie down bolt	–	○	–	○ (Initial fastening force)
		Immersion (15m)	Primary container body	–	△	–	–
			Primary container lid	–	△	–	–

○ : Evaluation in terms of combined load
△ : Evaluation in terms of single load

(d) Method of evaluation

The structural analysis under each of the conditions shall be implemented according to the flow shown in Fig.(II)-A.1.

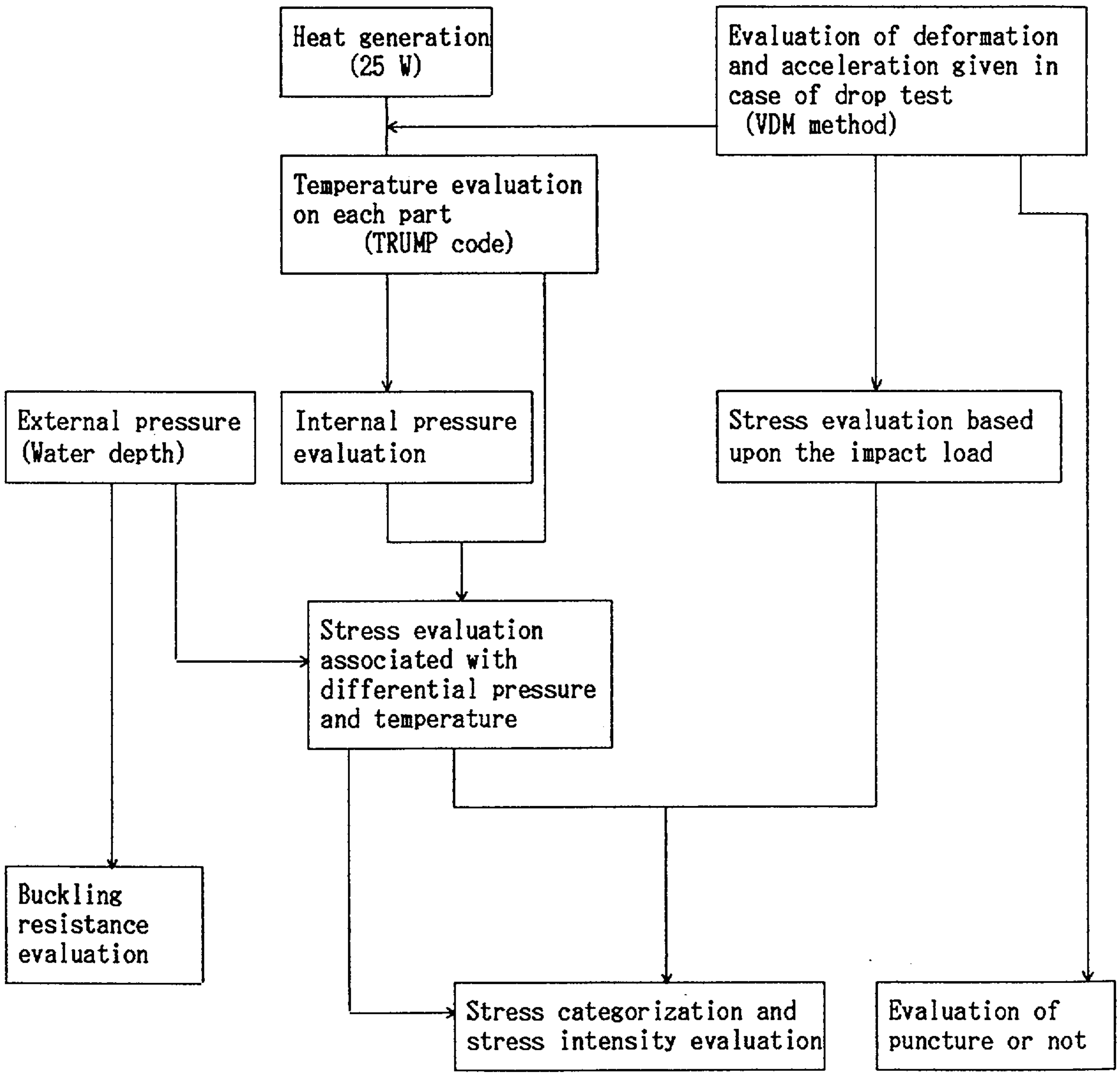

Fig.(II)-A.1 Structural analysis flow chart

Then, the design condition, method and the criteria of the structural design of the packaging are summarized in Table(II)-A.3.

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (1/14)

Symbol
σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Routine condition	1. Chemical and galvanic reactions								
	(1) Chemical reaction	—	—	Corrosion	—	Active	No chemical reaction accompanied	To be inactive	
	(2) Galvanic reaction	—	—	Corrosion	—	Potential difference	No electrical reaction accompanied	Without moisture contained	
	2. Low temperature								
	(1) Packaging	SUS304	−40℃	Material	—	Material degrading	Lowest service temperature	No brittleness fracture anticipated	
	(2) Bolt	SUS630	−40℃	Material	—	Material degrading	Lowest service temperature	No brittleness fracture anticipated	
	(3) O-ring	Al + Inconel	−40℃	Material	—	Material degrading	Lowest service temperature	−40℃	
	3. Containment system								
	(1) Primary container	SUS304	100℃	Possibility of contingency	—	Contigency or not	Misoperation permissible or not	Free of mis-operation	
	4. Lifting device								
	(1) Portion of eye bolt installation	SUS304	100℃	Weight of package	3	Tensile stress	$\sigma_t = \frac{F}{A}$	Sy	
					3	Shearing stress	$\tau = \frac{F}{A}$	0.6Sy	
					3	Composite stress	$\sigma = \sqrt{\sigma_t^2 + 4 \cdot \tau^2}$	Sy	
	5. Tie down device								
	(1) Upper eye plate	SS400	20℃	Combined acceleration	×2[g] (Longitudinal, vertical)	Bending stress	$\sigma_b = \frac{M}{Z}$	Sy	Z: Cross sectional coefficient
						Shearing stress	$\tau = \frac{F}{A}$	0.6Sy	
					×1[g] (Transversal)	Composite stress	$\sigma = \sqrt{\sigma_b^2 + 4 \cdot \tau^2}$	Sy	

Symbol
σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (2/14)

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Routine condition	6. Pressure								
	(1) Center of primary container body hull part	SUS304	100℃		1	Combined stress	Formula of thick wall cylinder	[Note 1]	[Note 1] Establish a reference value for each of stress categories on the basis of Sm taken as criteria
	(2) Center of primary container body bottom part	SUS304	100℃		1	Combined stress	Formula of disk plate periphery simply supported		[Note 2] Taking Sy as criteria, establish reference value for each of stress categories on the basis of Sy taken as criteria
	(3) Flange of primary container body	SUS304	100℃		1	Combined stress	Formula of ring plate outer periphery simply supported and inner periphery fixed	[Note 2]	
	(4) Center of primary container lid hull part	SUS304	100℃		1	Combined stress	Formula of thin wall of cylinder	[Note 1]	
	(5) Center of upper primary container lid (upper part)	SUS304	100℃		1	Combined stress	Formula of panel, internal pressure imposed		
	(6) Primary container lid flange part	SUS304	100℃	Atmospheric pressure drop 25 kPa	1	Bending stress	Formula of ring plate inner periphery simply fixed and outer periphery supported	[Note 2]	
	(7) Primary container lid inside O-ring part displacement	SUS304	100℃		1	Displacement (ω)	$\omega = \frac{Qa^2}{8\pi D}\left\{(1+A)\left(1-\frac{b^2}{a^2}\right) - \left(B+\frac{b^2}{a^2}\right)\cdot \ell_n \frac{a}{b}\right\}$ [1]	Initial displacement of O-ring	
	(8) Primary container lid tie down bolts	SUS630	100℃		1	Tensile stress	$\sigma = \frac{F}{A}$	[Note 2]	
	(9) Center of valve cover	SUS304	100℃		1	Combined stress	Formula of disk plate periphery simply supported	[Note 1]	
	(10) Valve cover tie down bolts	SUS630	100℃		1	Tensile stress	$\sigma = \frac{F}{A}$	[Note 2]	
	7. Vibration								
	(1) Package	SUS304	100℃	Vibration	1	Resonance	$f_o = \frac{1}{2\pi} \cdot \sqrt{\frac{k}{m}}$ f_o: Natural frequency of vibration	Vibration imposed during transport	

Symbol

σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (3/14)

Condition	Items of analysis	Design condition					Method of analysis		Remarks
		Material	Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Numerical equation applied or element	Analysis criteria	
Normal conditions of transport	1. Thermal test 1.1 Thermal expansion (1) Capsule & primary container	SUS304	100℃	Thermal expansion	1	Displacement	Whether or not provided any restraint due to thermal expansion.	No restraint improved.	
	1.2 Stress calculation (1) Center of capsule body hull part	SUS304	100℃	External pressure	1	Combined stress	$\sigma_\theta = -\frac{PDm}{2t}$ $\sigma_r = -\frac{P}{2}$ $\sigma_z = -\frac{PDm}{4t}$ Formula of thin wall cylinder	[Note 1]	[Note 1] Establish reference value for each of stress categories taking Sm as criteria [Note 2] Taking Sy as criteria, establish reference value for each of stress categories.
	(2) Center of capsule body bottom part	SUS304	100℃	External pressure	1	Combined stress	$\sigma_\theta = \sigma_r = \mp 1.24\frac{Pa^2}{h^2}$ $\sigma_z = -P$ Formula of disk plate periphery simply supported.	[Note 1]	
	(3) Center of primary container body hull part	SUS304	100℃	Internal pressure; thermal expansion	1	Combined stress	$\sigma_\theta = P\frac{Ro^2+R_i^2}{Ro^2-R_i^2}$ $\sigma_z = P\frac{R_i^2}{Ro^2-R_i^2}$ $\sigma_r = -P$ Formula of thick wall cylinder $\sigma_\theta = \sigma_z = \frac{E\cdot\alpha\cdot(T_1-T_2)}{2\cdot(1-\nu)}$	[Note 1]	
	(4) Center of primary container body bottom part	SUS304	100℃	Internal pressure	1	Combined stress	$\sigma_r = \sigma_\theta = \mp 1.24\frac{Pa^2}{h^2}$ $\sigma_z = -P$ Formula of disk plate periphery simply supported.	[Note 1]	

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Symbol

σ: Stress generated　F: Load
τ: Shear stress　P: Pressure
M: Bending moment　A: Cross sectional area

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (4/14)

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Normal conditions of transport	(5) Flange of primary container body	SUS304	100℃	Internal pressure	1	Combined stress	Formula of disk plate simply supported on the outer periphery and fixed on the inner periphery. [1] $\sigma_\theta = \mp \frac{3Q}{4\pi h^2}\{2(1+\nu)(A+\ell n\frac{a}{b}) + (1-\nu)(1-B\cdot\frac{a^2}{b^2})\}$ $\sigma_r = \mp \frac{3Q}{4\pi h^2}\{2(1+\nu)(A+\ell n\frac{a}{b}) - (1-\nu)(1-B\cdot\frac{a^2}{b^2})\}$	[Note 2]	[Note 1] Taking Sm as criteria, establish reference value for each of the stress categories [Note 2] Taking Sy as criteria, establish reference value for each of the stress categories
	(6) Center of primary container lid hull part	SUS304	100℃	Internal pressure	1	Combined stress	$\sigma_\theta = \frac{PDm}{2t}$ $\sigma_z = \frac{PDm}{4t}$ $\sigma_r = -\frac{P}{2}$ Formula of thin wall cylinder	[Note 1]	
	(7) Center of primary container lid upper part	SUS304	100℃	Internal pressure	1	Combined stress	$\sigma_\theta = \sigma_r = \frac{P\cdot R\cdot W}{2t} + 0.1P$ $\sigma_z = -\frac{P}{2}$ Formula of panel plate imposed by internal pressure	[Note 1]	
	(8) Flange of primary container lid	SUS304	100℃	Internal pressure	1	Combined stress	The same formula to be applied as given for the flange of (primary container body in article 1.2 (5).	[Note 2]	
	(9) Primary container lid inside O-ring displacement	SUS304	100℃	Internal pressure	1	Displacement	$\omega = \frac{Qa^2}{8\pi D}\{(1+A)(1-\frac{b^2}{a^2}) - (B+\frac{b^2}{a^2})\cdot \ell n(\frac{a}{b})\}$ [1]	Initial displacement of O-ring	
	(10) Primary container lid tie down bolts	SUS630	100℃	Internal pressure; initial fastening force; thermal expansion	1	Tensile stress	$\sigma = \frac{F}{A} + \frac{\pi b^2 P}{nA} + \frac{E_B(\alpha_S - \alpha_B)(T-T_0)}{1+\frac{A_B\cdot E_B}{A_S\cdot E_S}}$	[Note 2]	

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Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (5/14)

Symbol
σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Normal conditions of transport	(11) Center of valve cover	SUS304	100℃	Internal pressure	1	Combined stress	$\sigma_\theta = \sigma_r = \mp \frac{3Pb^2}{8h^2} \times \{4\cdot(1+\nu)\cdot \ell_n \frac{a}{b} + 4 - (1-\nu)\cdot \frac{b^2}{a^2}\}$ $\sigma_z = -P$ Formula of disk plate periphery simply supported. [1]	[Note 1]	[Note 1] Taking Sm as criteria, establish reference value for each of the stress categories [Note 2] Taking Sy as criteria, establish reference value for each of the stress categories
	(12) Valve cover fastening bolts	SUS630	100℃	Internal pressure; initial fastening force; thermal expansion	1	Tensile stress	$\sigma = \frac{F}{A} + \frac{\pi a^2 P}{nA} + \frac{E_B(\alpha_S - \alpha_B)(T-T_0)}{1+\frac{A_B\cdot E_B}{A_S\cdot E_S}}$	[Note 2]	
	2. Water spray			Water spray	1	Moisture absorption Draining	Moisture absorptive Easy to be drained.	To be free of moisture absorption Facilitated with drainage	

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (6/14)

Symbol

σ: Stress generated　F: Load

τ: Shear stress　P: Pressure

M: Bending moment　A: Cross sectional area

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Normal conditions of transport	3. Free drop								
	3.1 Bottom end vertical drop								
	(1) Deformation of shock absorber	—	—	1.2 m bottom end vertical drop	1	Deformation	$x = \ell_o - \delta_o - \delta_i$ * ℓ_o ; Shock absorbers thickness before drop X ; Thickness after drop	217mm	[Note 1] Taking Sm as criteria, establish reference value for each of the stress categories [Note 2] Taking Sy as criteria, establish reference value for each of the stress categories * δ_o : external deformation of protective container δ_i : internal deformation of protective container
	(2) Capsule nozzle	SUS304	100℃	1.2 m bottom end vertical drop	1	Tensile stress	$\sigma = \frac{F}{A}$	[Note 1]	
	(3) Capsule flange	SUS304	100℃	1.2 m bottom end vertical drop	1	Combined stress	Formula of ring plate simply supported on the outer periphery and fixed on inner periphery.	[Note 1]	
	(4) Center of capsule body hull part	SUS304	100℃	1.2 m bottom end vertical drop	1	Tensile stress	$\sigma = \frac{F}{A}$	[Note 1]	
	(5) Center of primary container body hull part	SUS304	100℃	1.2 m bottom end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 1]	
	(6) Valve cover fastening bolt	SUS630	100℃	1.2 m bottom end vertical drop	1	Bending stress	$\sigma = \frac{M \cdot \ell max}{I}$	[Note 2]	
	3.2 Top end vertical drop								
	(1) Deformation of shock absorber	—	—	1.2 m top end vertical drop	1	Deformation	$x = \ell_o - \delta_o - \delta_i$ * ℓ_o ; Shock absorbers thickness before drop X ; Thickness after drop	217mm	
	(2) Capsule nozzle	SUS304	100℃	1.2 m top end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 1]	
	(3) Capsule flange	SUS304	100℃	1.2 m top end vertical drop	1	Combined stress	Formula of ring plate simply supported on the outer periphery and fixed on inner periphery.	[Note 1]	
	(4) Capsule flange tie down bolts	SUS630	100℃	1.2 m top end vertical drop	1	Tensile stress	$\sigma = \frac{F}{A}$	[Note 2]	
	(5) Capsule body hull part	SUS304	100℃	1.2 m top end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 1]	
	(6) Primary container lid hull part	SUS304	100℃	1.2 m top end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 1]	

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Symbol

σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (7/14)

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Normal conditions of transport	(7) Center of primary container lid (upper part)	SUS304	100℃	1.2 m top vertical end drop	1	Combined stress	$\sigma_\theta = \sigma_r = -\left(\frac{P \cdot R \cdot W}{2t} + 0.1P\right)$ [2] $\sigma_z = -\frac{P}{2}$	[Note 1]	[Note 1] Taking Sm as criteria, establish reference value for each of the stress categories [Note 2] Taking Sy as criteria, establish reference value for each of the stress categories
	(8) Valve cover tie down bolts	SUS630	100℃	1.2 m top vertical end drop	1	Bending stress	$\sigma = \frac{M \cdot \ell \max}{I}$	[Note 2]	
	3.3 Horizontal drop (1) Deformation on shock absorber	—	—	1.2 m horizontal drop	1	Deformation	$x = \ell_{o2} - \delta_o - \delta_i$ * ℓ_{o2} ; Shock absorbers thickness before drop x ; Thickness after drop	117mm	* δ_o : external deformation of protective container δ_i : internal deformation of protective container
	(2) Capsule nozzle	SUS304	100℃	1.2 m horizontal drop	1	Bending stress	$\sigma = \frac{3Ed_2C}{\ell_2(2\ell_2 + 3\ell_1)}$	[Note 1]	
						Shearing stress	$\tau = \frac{F}{A}$		
	(3) Capsule body hull part	SUS304	100℃	1.2 m horizontal drop	1	Bending stress	$\sigma = \frac{M}{Z}$		
		SUS304	100℃	1.2 m horizontal drop	1	Combined stress	$\sigma_\theta = -1.492 \frac{[12 \cdot (1-P^2)]^{1/8} \cdot R^{3/4} \cdot F}{L^{1/2} \cdot t^{5/4}}$ [1] $\sigma_\theta' = -1.217 \frac{R^{1/4} \cdot L^{1/2} \cdot F}{[12 \cdot (1-\nu^2)]^{1/8} \cdot t^{7/4}}$ $\sigma_z = -0.1188 \frac{[12 \cdot (1-\nu^2)]^{3/8} \cdot R^{1/4} \cdot L^{1/2} \cdot F}{t^{7/4}}$		
	(4) Capsule flange fixing bolts	SUS630	100℃	1.2 m horizontal drop	1	Bending stress	$\sigma = \frac{M \cdot \ell_{max}}{I}$	[Note 2]	
	(5) Center of primary container body	SUS304	100℃	1.2 m horizontal drop	1	Compressive stress	$\sigma = 0.591 \cdot \sqrt{F \cdot E \frac{D_1 - D_2}{D_1 D_2}}$	[Note 1]	
	(6) Primary container lid tie down bolts	SUS630	100℃	1.2 m horizontal drop	1	Bending stress	$\sigma = \frac{M \cdot \ell \max}{I}$	[Note 2]	
	(7) Primary container lid hull part	SUS304	100℃	1.2 m horizontal drop	1	Bending stress	$\sigma = \frac{M}{Z}$	[Note 1]	

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (8/14)

Symbol

σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Condition	Items of analysis	Design condition					Method of analysis		Remarks
		Material	Tempe-rature	Design load: Kind	Load factor	Element	Numerical equation applied or element	Analysis criteria	
Normal conditions of transport	3.4 Corner drop								[Note 2] Taking Sy as criteria, establish reference value for each of the stress categories.
	3.4.1 Bottom end corner drop								
	(1) Deformation of shock absorber			1.2 m bottom end corner drop	1	Evaluation provided on the horizontal & vertical drop components		245.1mm	
	3.4.2 Top end corner drop								
	(1) Deformation of shock absorber			1.2 m top end corner drop	1	Evaluation provided on the horizontal and vertical drop components		254.5mm	
	(2) Primary container lid tie down bolts	SUS630	100℃	1.2 m top end corner drop	1	Bending stress	$\sigma = \frac{M \cdot \ell max}{I}$	[Note 2]	ANSTEC APERTURE CARD Also Available on Aperture Card
	3.5 Oblique drop								
	(1) Deformation of shock absorber —	—	—	1.2 m oblique drop	1	Evaluation provided on the horizontal & vertical components		Depending upon the drop angle	
	4. Stacking test (1) Protective container hull part	SUS304	100℃	5 times the weight of package	1	Compressive stress	$\sigma = \frac{F}{A}$	Sy	
	5. Puncture (1) Protective container outer plate	SUS304	100℃	Drop impact of mild steel bar	1	Absorbed energy	$E_2 = \frac{1}{2} \tau_{cr} \cdot \pi \cdot d \cdot t^2$ (τ_{cr}: Allowable shear strength)=0.6Su	5.89×10^4 N・mm	
	(2) Fusible plug part	SUS304	100℃	Drop impact of mild steel bar	1	Absorbed energy			

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Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (9/14)

Symbol
σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Accident conditions of transport	1. Drop test I								
	1.1 Bottom end vertical drop								
	(1) Deformation of shock absorber	—	—	9 m bottom end vertical drop	1	Deformation	$x = \ell_o - \delta_o - \delta_i$ ‡ ℓ_o ; Shock absorbers thickness before drop X ; thickness after drop	217mm	
	(2) Capsule nozzle	SUS304	100℃	9 m bottom end vertical drop	1	Tensile stress	$\sigma = \frac{F}{A}$	[Note 3]	[Note 3] Taking Su as criteria, establish reference value for each of the stress categories
	(3) Capsule flange	SUS304	100℃	9 m bottom end vertical drop	1	Combined stress	Formula of ring plate simply supported on the periphery		
	(4) Center of primary container body hull part	SUS304	100℃	9 m bottom end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 3]	‡ δ_o : external deformation of protective container
	(5) Center of capsule body hull part	SUS304	100℃	9 m bottom end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 3]	δ_i : internal deformation of protective container
	(6) Valve cover tie down bolts	SUS630	100℃	9 m bottom drop	1	Bending stress	$\sigma = \frac{M \cdot \ell_{max}}{I}$	[Note 2]	
	1.2 Top end vertical drop								
	(1) Deformation of shock absorber	—	—	9 m top end vertical drop	1	Deformation	$x = \ell_o - \delta_o - \delta_i$ ‡ ℓ_o ; Shock absorbers thickness before drop X ; thickness after drop	217mm	
	(2) Capsule nozzle	SUS304	100℃	9 m top end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 3]	
	(3) Capsule flange	SUS304	100℃	9 m top end vertical drop	1	Combined stress	Formula of ring plate simply supported on the periphery		
	(4) Capsule flange fixing bolt	SUS630	100℃	9 m top end vertical drop	1	Tensile stress	$\sigma = \frac{F}{A}$	[Note 2]	[Note 2] Taking Sy as criteria, establish reference value for each of the stress categories.
	(5) Center of capsule body hull part	SUS304	100℃	9 m top end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$	[Note 3]	
	(6) Center of primary container lid hull part	SUS304	100℃	9 m top end vertical drop	1	Compressive stress	$\sigma = \frac{F}{A}$		

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Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (10/14)

Symbol
σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Condition	Items of analysis	Design condition: Material	Tempe-rature	Design load: Kind	Load factor	Element	Method of analysis: Numerical equation applied or element	Analysis criteria	Remarks
Accident conditions of transport	(7) Center of primary container lid upper part	SUS304	100℃	9 m top end vertical drop	1	Combined stress	$\sigma_\theta = \sigma_r = -\left(\frac{P\cdot R\cdot W}{2t} + 0.1P\right)^{(2)}$ $\sigma_z = -\frac{P}{2}$	[Note 3]	[Note 3] Taking Su as criteria, establish reference value for each of the stress categories [Note 2] Taking Sy as criteria, establish reference value for each of the stress categories.
	(8) Valve cover tie down bolts	SUS630	100℃	9 m top end vertical drop	1	Bending stress	$\sigma = \frac{M\cdot \ell_{max}}{I}$	[Note 2]	
	1.3 Horizontal drop (1) Deformation of shock absorber	—	—	9 m horizontal drop	1	Deformation	$x = \ell_o - \delta_o - \delta_i$ * ℓ_o ; Shock absorbers thickness before drop x ; Thickness after drop	117mm	* δ_o : external deformation of protective container δ_i : internal deformation of protective container
	(2) Capsule nozzle	SUS304	100℃	9 m horizontal drop	1	Bending stress Shearing stress	$\sigma = \frac{3Ed^2\cdot C}{\ell_2(2\ell_2+3\ell_1)}$ $\tau = \frac{F}{A}$	[Note 3]	
	(3) Capsule body hull part	SUS304	100℃	9 m horizontal drop	1	Bending stress	Formula equivalent to that applied for capsule body hull part provided 3.3 (3) in the normal conditions of transport.		
	(4) Capsule flange fixing bolts	SUS630	100℃	9 m horizontal drop	1	Bending stress	$\sigma = \frac{M\cdot \ell_{max}}{I}$	[Note 2]	
	(5) Primary container body hull part	SUS304	100℃	9 m horizontal drop	1	Compressive stress	$\sigma = 0.591\cdot\sqrt{F\cdot E\,\frac{D_1-D_2}{D_1D_2}}$	[Note 3]	
	(6) Primary container lid fastening bolts	SUS630	100℃	9 m horizontal drop	1	Bending stress	$\sigma = \frac{M\cdot \ell\, max}{I}$	[Note 2]	
	(7) Primary container lid hull part	SUS304	100℃	9 m horizontal drop	1	Bending stress	$\sigma = \frac{M}{Z}$	[Note 3]	

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Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging(11/14)

Symbol

σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Accident conditions of transport	1.4 Corner drop								
	1.4.1 Bottom end corner drop								[Note 2] Taking Sy as criteria, establish reference value for each of the stress categories
	(1) Deformation	—	—	9 m bottom end corner drop	1	Evaluation provided on horizontal & vertical components		245.1mm	
	1.4.2 Top end corner drop								
	(1) Deformation	—	—	9 m top end corner drop	1	Evaluation provided on horizontal & vertical components		254.5mm	
	(2) Primary container lid tie down bolts	SUS630	100℃	9 m top end corner drop	1	Bending stress	$\sigma = \frac{M \cdot \ell_{max}}{I}$	[Note 2]	
	1.5 Oblique drop								
	(1) Deformation			9 m oblique drop	1	Evaluation provided on horizontal & vertical components		Depending upon drop angle	

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Symbol
σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (12/14)

Condition	Items of analysis	Design condition					Method of analysis		Remarks
		Material	Tempe-rature	Design load			Numerical equation applied or element	Analysis criteria	
				Kind	Load factor	Element			
Accident conditions of transport	2. Drop test II								
	2.1 Puncture								ε: Deformation strain δ: Deformation d: Diameter mild steel bar
	(1) Protective container lid part	SUS304	100℃	1 m drop impact	1	Steel plate extension	$\varepsilon = \frac{1.14\delta}{2\delta + d}$	40%	
	(2) Protective container hull part	SUS304	100℃	1 m drop impact	1	Steel plate extension			
	(3) Protective container bottom part	SUS304	100℃	1 m drop impact	1	Steel plate extension			
	3. Thermal test								
	3.1 Thermal expansion								
	(1) Capsule & primary container	SUS304	200℃	Thermal expansion	1	Displacement	Whether or not any restraint involved due to thermal expansion.	Free of any restraint involved	

Symbol
σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging (13/14)

Condition	Items of analysis	Design condition: Material	Design condition: Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Method of analysis: Numerical equation applied or element	Method of analysis: Analysis criteria	Remarks
Accident conditions of transport	3.2 Thermal test								
	(1) Center of capsule body hull part	SUS304	200℃	Internal pressure	1	Combined stress	Analysis will be conducted with the same procedure at the same position as those employed in 1.2 stress calculation.	[Note 3]	[Note 3] Taking Su as criteria, establish reference value for each of the stress categories [Note 2] Taking Sy as criteria, establish reference value for each of the stress categories.
	(2) Center of capsule body bottom part	SUS304	200℃	Internal pressure	1	Combined stress		[Note 3]	
	(3) Center of primary container body hull part	SUS304	200℃	Internal pressure	1	Combined stress		[Note 3]	
	(4) Center of primary container body bottom part	SUS304	200℃	Internal pressure	1	Combined stress		[Note 3]	
	(5) Flange of primary container body	SUS304	200℃	Internal pressure	1	Combined stress		[Note 2]	
	(6) Primary container lid hull part	SUS304	200℃	Internal pressure	1	Combined stress		[Note 3]	
	(7) Center of primary container lid upper part	SUS304	200℃	Internal pressure	1	Combined stress		[Note 3]	
	(8) Primary container lid flange part	SUS304	200℃	Internal pressure	1	Combined stress		[Note 2]	
	(9) Primary container inside O-ring part	SUS304	200℃	Internal pressure	1	Displacement		Initial displacement of O-ring	
	(10) Primary container lid tie down bolts	SUS630	200℃	Internal pressure, initial fastening force, thermal expansion	1	Tensile stress		[Note 2]	
	(11) Center of valve cover	SUS304	200℃	Internal pressure	1	Combined stress		[Note 3]	
	(12) Valve cover tie down bolts	SUS630	200℃	Internal pressure, initial fastening force, thermal expansion	1	Tensile stress		[Note 2]	

Table(II)-A.3 Condition and Method of Analysis of the Structural Design of Packaging(14/14)

Symbol

σ: Stress generated F: Load
τ: Shear stress P: Pressure
M: Bending moment A: Cross sectional area

Condition	Items of analysis	Design condition					Method of analysis		Remarks
		Material	Temperature	Design load: Kind	Design load: Load factor	Design load: Element	Numerical equation applied or element	Analysis criteria	
Accident conditions of transport	4. Immersion								[Note 3] Taking Su as the criteria, establish reference value for each of the stress categories
	(1) Primary container lid hull part	SUS304	100℃	External pressure	1	Buckling load	$Pe = \frac{4B \cdot t}{2Do}$ B ; Shape factor Do; Container outer diameter	Free of buckling	
	(2) Center of primary container lid hull part	SUS304	100℃	External pressure	1	Combined stress	$\sigma_\theta = -\frac{PDm}{2t}$ $\sigma_z = -\frac{PDm}{4t}$ $\sigma_r = -\frac{P}{2}$ Formula of thin wall cylinder	[Note 3]	
	(3) Center of primary container upper part container	SUS304	100℃	External pressure	1	Combined stress	$\sigma_\theta = \sigma_r = -(\frac{P \cdot R \cdot W}{2t} + 0.1P)$ [2] $\sigma_z = -\frac{P}{2}$	[Note 3]	
	(4) Primary container body hull part	SUS304	100℃	External pressure	1	Buckling load	$Pe = \frac{4B \cdot t}{2Do}$ B ; Shape factor Do; Container outer diameter	Free of buckling	
	(5) Center of primary container body hull part	SUS304	100℃	External pressure	1	Combined stress	$\sigma_\theta = -P \frac{Ro^2 + Ri^2}{Ro^2 - Ri^2}$ $\sigma_r = -P \frac{Ro^2}{Ro^2 - Ri^2}$ $\sigma_z = -P$ Equation of thick wall cylinder	[Note 3]	
	(6) Center of primary container body bottom part	SUS304	100℃	External pressure	1	Combined stress	Equation as same as given in Item 1.2(4).	[Note 3]	

A.2 Weight and center of gravity

The weight of this package is approx. 450 kg, and the location of center of gravity is given as shown in Fig.(II)-A.2.

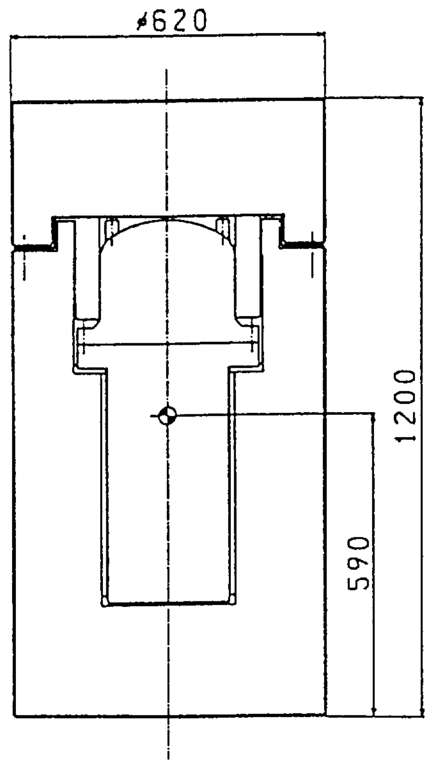


Fig.(II)-A.2 Location of center of gravity

A.3 Package's criteria

A.3.1 Chemical and galvanic reaction

The materials contacting with each other inside the packaging during the normal transport are mainly those given in the following, which are free of any particular chemical or galvanic reaction with each other : -

Stainless steel - Copper plate

Stainless steel - Aluminum

Stainless steel - Silicon rubber

Stainless steel - ZrCo

Stainless steel - Balsa wood

Stainless steel - Solder

Stainless steel - Ethylene propylene

Copper plate - Balsa wood

A.3.2 Low temperature strength

As for the employed materials and components of the containment system, the charactaristics under low temperature condition(-40℃) are as follows

① Austenitic stainless steel(Type 304) ② Aluminium (Material of spacer body)	free of fracture due to brittleness
③ Precipitation hardened steel(Type 630)	the brittleness transition temperature is lower than -40℃
④ Metal O-ring	: there is no difference between the load-displacement relation at room temperature and that at -40℃
⑤ Silicon Rubber	: the lowest service temperature is lower than -40℃
⑥ Balsa-wood	: there is no significant difference between the stress-strain relation at room temp. and that at -40℃

A.3.3 Containment

The primary container will be fastened with the primary container lid by bolts after the capsule being installed therein, thereafter contained into the protective container so that it is kept closed as well as the valves thereon kept out of unintentional opening.

A.3.4 Lifting device

As for the lifting device, evaluation has been undertaken to verify the stress generated being lower than the design yield stress under the design load which is taken 3 times the nominal loading. (The results of the evaluation are shown in Table(II)-A.7)

A.3.5 Tie down device

As for the tie down device, evaluation has been implemented on the basis of the guideline which is given by Japanese Competent Authority, where it has been verified that the stress generated is lower than the design yield stress. (The results of the evaluation are shown in Table(II)-A.8)

A.3.6 Pressure

The integrity of primary container has been evaluated under the condition that the external pressure is reduced to 25 kPa. (The results of the evaluation are shown in Table(II)-A.9)

A.3.7 Vibration

The natural frequency of vibration under the status of transportation of the package, namely, the natural frequency of the vibration of the package placed in a fastened stance through the eyeplate in vertical attitude has been calculated, and it has been verified that the natural frequency of the package(which is approx. 300 Hz), is significantly higher than the frequency of vibration imposed on the package during transportation(which is approx. 0 ~ 50 Hz), so that it is free of resonance.

A.4 Normal conditions of transport

A.4.1 Design pressure and temperature

① Design temperature

The design temperature has been defined as 100℃, taking an adequate margin against the result of thermal analysis, under which the structural evaluation has been implemented.

② Design pressure

i) Pressure inside the primary container

The design internal pressure of primary container has been defined by giving an adequate margin to the maximum normal operating pressure(0.056 MPa·G) which is obtained in B.3 of thermal analysis.

ii) Capsule

The inside of the capsule is in vacuum initially, and it will be pressurized during transportation with helium gas generated by decaying of tritium ; however the internal pressure of the capsule will be so defined as to make the maximum differential pressure between the primary container and capsule internal pressures for the purpose of structural evaluation.

Considering the above, the design temperature and design pressure of the package are defined are shown in Table(II)-A.4.

Table(II)-A.4 Design pressure

Location	Normal conditions of transport			Accident conditions of transport (thermal test)	
	Design temperature(℃)		Design pressure(MPa・G)	Design temperature(℃)	Design pressure(MPa・G)
	Maximum	Minimum			
Protective container	100	-40	(-)	(-)	(-)
Primary container	100	-40	0.071	200	0.121
Capsule	100	-40	-0.101	200	-0.101

A.4.2 Thermal test

The following has been implemented on the basis of design temperature and design pressure so as to verify the integrity of the package.

① The effect of thermal expansion differences between adjacent structural components.

② Stress evaluation and displacement investigation of the containment devices under the considering of internal pressure and thermal expansion. (The results of the evaluation are shown Table(II)-A.10)

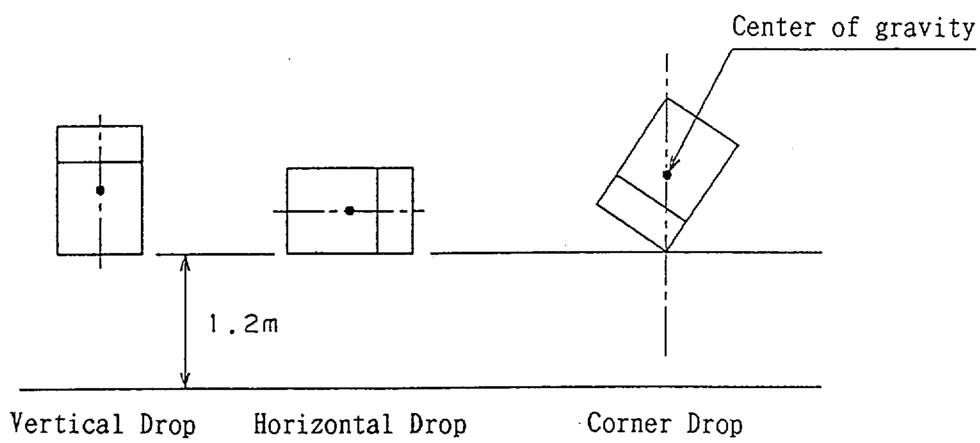
A.4.3 Water spray

All of the material employed as the external surface of the package is stainless steel, free of any moisture absorption, so that no degrading of the structure will be anticipated by corrosion, and the lid part of protective container is provided with packing, so that no moisture intrusion will be anticipated proceeding inside the package by the water tight structure.

A.4.4 Free drop

The weight of package is approx. 450 kg, and the height of drop to be applied the package is 1.2 m in the normal test condition.

The evaluation of generating acceleration will be executed by VDM method, (volumetric displacement method), the calculated accelerations and deformations assosiated with each of the drop tests, in the vertical, the horizontal and in the corner drop are given by VDM method as follows : -



Table(II)-A.5 Accelerations and deformations under 1.2 m free drop

Attitude		Drop angle [°]	Acceleration [×g]	Deformation [mm]
Horizontal		90°	440	approx. 20
Vertical	Top end	0°	170	approx. 35
	Bottom end		170	approx. 30
Corner	Top end	26.9°	450*	approx. 55
	Bottom end	27.7°	450*	approx. 55

* Vertical component : 160·g

* Horizontal component : 420·g

Where

g : gravitational acceleration $g = 9.81[m/s^2]$

(Note) o The deformation is taken as the sum of the deformation of internal surface of protective container and the deformation of external surface of the protective container.

o The impact energy absorption of the primary container and the capsule shall be made by the deformation of the balsa wood and that of the protective container shall be made by the deformation of this steel plate of protective container.

It has been verified that the stress generated in the containment system does not exceed the design criteria when a acceleration is imposed thereon. (The results of the evaluations are shown in Table(II)-A.11 ~ Table(II)-A.15)

A.4.5 Penetration

When a ϕ32 mm steel rod having 6 kg of weight is dropped from a hight of 1 m, the potential energy is 5.89×10^4[J], this value is smaller than the smallest energy to penetrate the external plate or fusible plug part of the protective container(9.52×10^4[J]), therefore no puncture occurs upon any part of protective container.

A.4.6 Stacking test

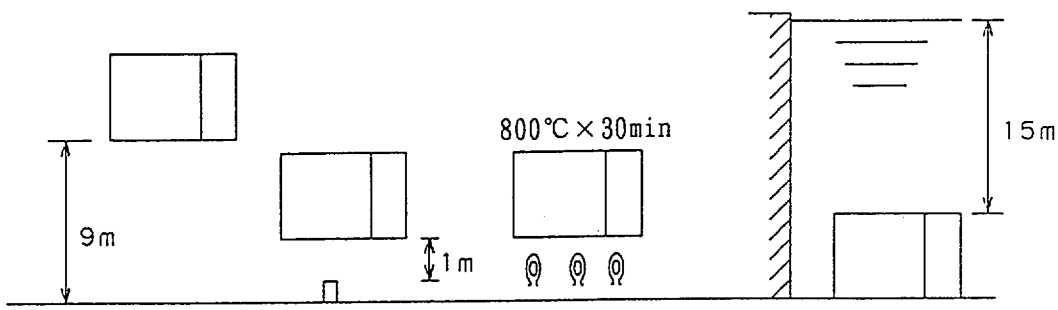
It has been verified that the protective container may keep its integrity maintained even in the case of where 5 times the self weight is loaded on the package. (The results of the evaluation are shown in Table(II)-A.16)

A.5 Accident conditions of transport

As the accident test condition, the state of the package shall be evaluated when the package is implemented under the followings :

① Drop test Ⅰ, ② Drop test Ⅱ, ③ Thermal test and, ④ Immersion test.

The sequence of the test ① and ② shall be specified ① to ② in order that the effects might be superimposed with each other.



① Drop test Ⅰ ② Drop test Ⅱ ③ Thermal test ④ Immersion test

A.5.1 Drop test Ⅰ

Evaluation is undertaken in this case as like as the case of 9 m free drop test in which VDM method is to be applied.

The generating accelerations and deformations associated with each of the vertical, horizontal and corner drop tests are shown as follows.

Table(II)-A.6 Acceleration and deformation under 9 m drop test

	Shock absorber analysis position	Shock absorber's minimum thickness before drop (mm)	Shock ** absorber deformation (mm)	Shock absorber's minimum thickness after drop (mm)	Acceleration (g)
Vertical drop	Top end part	217	approx. 155	approx. 70	370
	Bottom end part	217	approx. 150	approx. 75	370
Horizontal drop	Cylindrical part	117	approx. 90	approx. 30	640
Corner drop	Top end part	245	approx. 170	approx. 75	625*
	Bottom end part	260	approx. 150	approx. 115	625*

* Horizontal component : 530·g
Vertical component : 330·g

**Sum of internal δi and external deformation δo of the protective container

It has been verified that the stress generated on the containment system, etc. is lower than the criteria, the integrity being maintained even in case the above accelerations imposed thereon.

(The results of the evaluations are shown in Table(II)-A.17 ~ Table(II)-A.21)

A.5.2 Drop test II (1 m puncture)

It has been verified that no puncture occurs on the protective container or the sum of deformation by drop test I and II does not attain to the primary container by comparing the extention of the porotective container's external plate by the impact energy with the maximum elongation of stainless steel when it is dropped from a height of 1 m onto a ϕ150 mm mild steel bar after being subjected to the drop test I.(The results of the evaluation are shown in Table(II)-A.22)

A.5.3 Thermal test

The stress associated with internal pressure and temperature of the containement vesssel(the capsule and primary container) during and after its being subjected to a 800℃×30 minutes thermal test has been evaluated and it is concluded that actual stress is lower than allowable stress criteria. (The results of the evaluations are shown in Table(II)-A.23)

A.5.4 Immersion test

Buckling and stress evaluation of the primary container has been undertaken when as external pressure is imposed associated with the package being subjected to 15 m water depth immersion, and it is verified that no damage incurred thereon. (The results of the evaluations are shown in Table(II)-A.24)

A.6 Stress evaluation results

The stress evaluation results in this structural analysis are summarized in Table(II)-A.7 ~ Table(II)-A.24.

As for all of the evaluations items, the values of the margin of safety are larger than 0, therefore it is demonstrated that the package is satisfied with the structural criteria.

A.7 Referenced documents

[1] J. Roark "Formulas for Stress and Strain"
5th ed. MoGraw - Hill Co.

[2] Technical Standards for Structure, etc., Regarding Nuclear Power Facilities for Generating Electric Power
(Official Notification No501, 1980)

Table (II)-A.7 Result of Evaluation of the Stress Imposed on the Lifting Device Under the Routine Condition

Conditions	Items of analysis	Load	Design criteria	Value of design criteria [N/mm^2]	Analysis result [N/mm^2]	MS
Routine condition	Lifting device Portion of eye bolt installation	3 times the weight of package				
	(1) Tensile stress		Sy	171	20.2	7.46
	(2) Shear stress		0.6Sy	103	20.2	4.10
	(3) Combined stress		Sy	171	45.2	2.78

Sy: Design yield strength MS: Margin of safety

Table (II)-A. 8 Summary of Results of Evaluation of Stress Imposed on the Tie Down Device under the Routine Condition

Unit of analysis standard values and analysis results; N/mm^2

Condition	Items of analysis			Kinds of loads	Design criteria	Analysis standard value	Analysis results	MS
Routine condition	Tie down device Upper eyeplate of tie down device A-A* section	(1)	Shear stress	2g for longitudical 2g for vertical and 1g for trasvessel	0.6 Sy	147	13.7	9.72
	B-B* section	(1)	Bending stress		Sy	245	13.3	17.4
		(2)	Shear stress		0.6 Sy	147	4.16	34.3
		(3)	Combined stress		Sy	245	15.7	14.6
	B-B section (welding part)	(1)	Bending stress		Sy	245	29.6	7.27
		(2)	Shear stress		0.6 Sy	147	9.23	14.92
		(3)	Combined stress		Sy	245	34.9	6.02
	C-C* section	(1)	Tensile stress		Sy	245	1.76	138
	C-C section (welding part)	(1)	Tensile stress		Sy	245	3.91	61.6

Sy: Design yield strength MS: Margin of safety

Sec A-A, B-B and C-C ; See Fig.(II)-A.3, 4 and 5

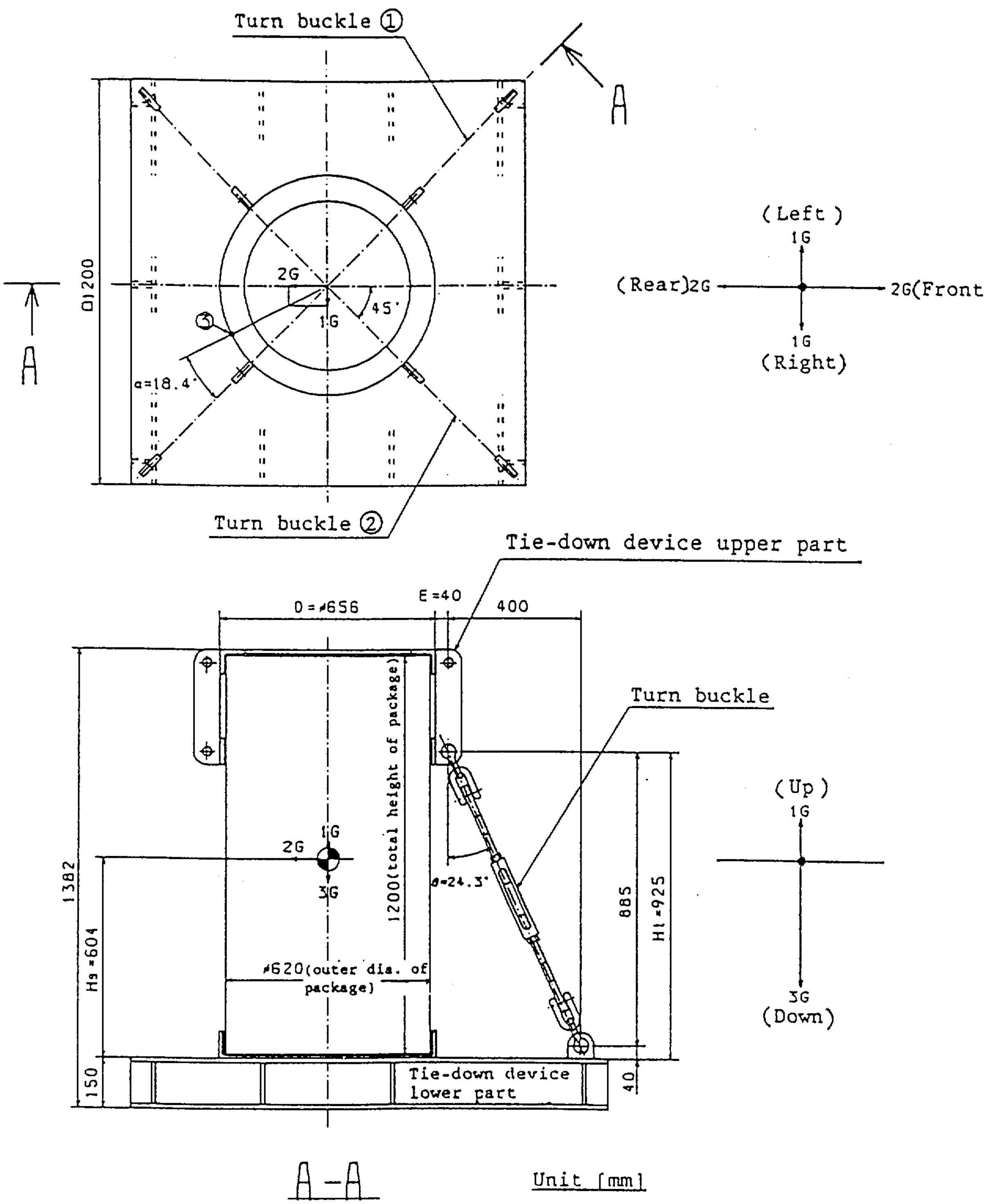


Fig.(II)-A.3 Acceleration during transport

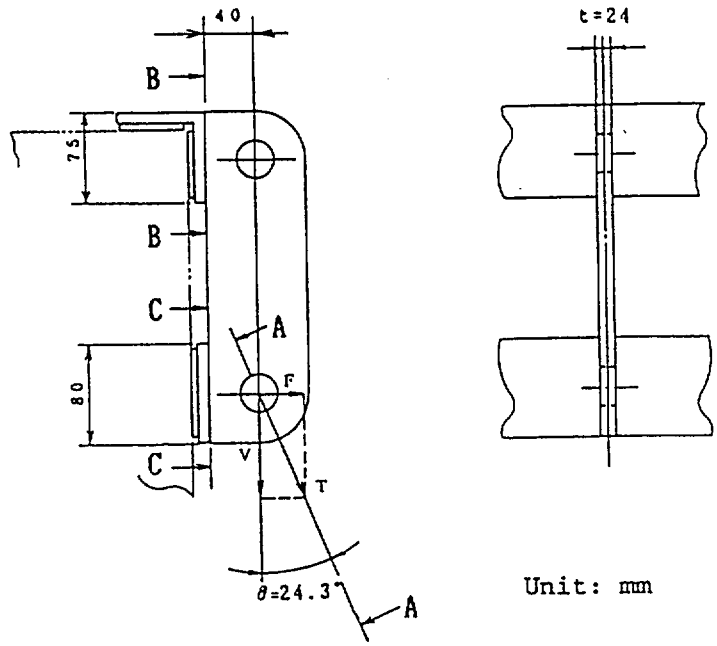


Fig.(II)-A.4 Analysis model associated with the tie-down device upper part eyeplate

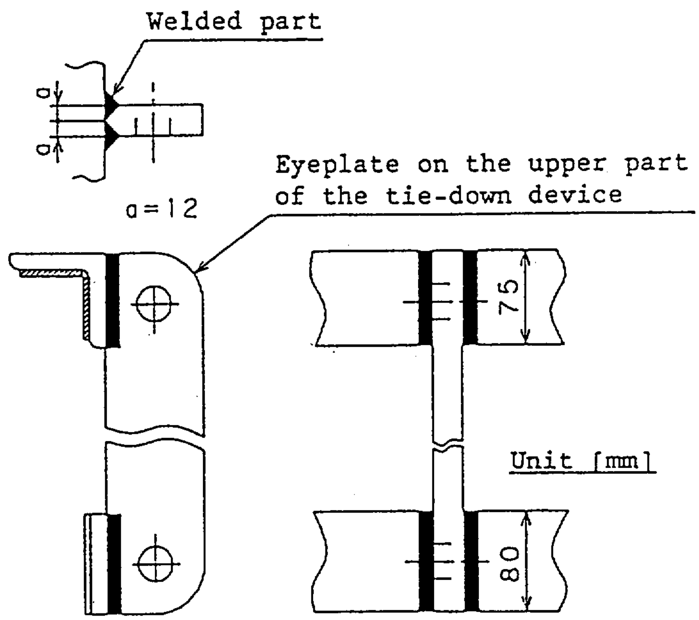


Fig.(II)-A.5 Analysis model associated with the welded part of the eyeplate

Table(II)-A.9 Results of Stress Evaluation under Variation of Pressure (1/3)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Evaluation of primary stress intensity: Pm(P$_L$)	Sm	MS	P$_L$+P$_b$	1.5Sm	MS	Evaluation of composite stress intensity (primary + secondary): P$_L$+P$_b$+Q	3Sm	MS	Fatigue evaluation: P$_L$+P$_b$+Q+F	Sa	N	Na	DF	MS
Ⓐ	Center of primary container body hull part		σ_r		−0.147	−															
			σ_θ	−	0.23	4.57	0.38	137	359.5	−	−	−	4.95	411	82.0	4.95	2.48	100	≥ 10^6	1×10^{-4}	1×10^4
			σ_z		0.04	4.57															
Ⓑ	Center of primary container body bottom part	Internal surface	σ_r		−5.92(b)																
			σ_θ	−	−5.92(b)	−															
			σ_z		−0.147		0.074	137	1.85×10^3	5.92	206	33.7	5.92	411	68.4	5.92	2.96	100	≥ 10^6	1×10^{-4}	1×10^4
		External surface	σ_r		5.92(b)																
			σ_θ	−	5.92(b)	−															
			σ_z		0																
Ⓒ	Flange of primary container body	Upper surface	σ_r		−1.30(b)																
			σ_θ	−	−0.39(b)	−															
			σ_z		−		−	−	−	1.30	Sy =171	130.5	1.30	Sy =171	130.5	1.30	0.65	100	≥ 10^6	1×10^{-4}	1×10^4
		Lower surface	σ_r		1.30(b)																
			σ_θ	−	0.39(b)	−															
			σ_z		−																
Ⓓ	Center of primary container lid hull part		σ_r		−0.074																
			σ_θ	−	2.04	−	2.11	137	63.9	−	−	−	2.11	411	193.7	2.11	1.06	100	≥ 10^6	1×10^{-4}	1×10^4
			σ_z		1.02																

Pm; Primary membrane stress P$_L$: Primary local membrane stress P$_b$; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

Table(II)-A.9 Results of Stress Evaluation under Variation of Pressure (2/3)

Unit of stress & stress intensity: N/mm²

Symbol	Stress and stress intensity / Location where evaluation conducted			Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Evaluation of primary stress intensity						Evaluation of composite stress intensity (primary + secondary)			Fatigue evaluation					
							$P_m(P_L)$	Sm	MS	P_L+P_b	1.5Sm	MS	P_L+P_b+Q	3Sm	MS	P_L+P_b+Q+F	Sa	N	Na	DF	MS
Ⓔ	Center of primary container body lid upper part		σ_r		2.17	–	2.24	137	60.1	–	–	–	2.24	411	182.4	2.24	1.12	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		2.17																
			σ_z		−0.074																
Ⓕ	Primary container lid flange part	Upper surface	σ_r	–	2.05(b)	–	–	–	–	2.05	Sy =171	82.4	2.05	Sy =171	82.4	2.05	1.03	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		0.62(b)																
			σ_z		–																
		Lower surface	σ_r	–	−2.05(b)	–															
			σ_θ		−0.62(b)																
			σ_z		–																
	Primary container lid inside O-ring displacement			① Displacement $\omega=3.02\times10^{-4}$ [mm] ② Initial displacement of O-ring $\delta=1.1$ [mm] ③ Residual displacement of O-ring $\Delta t=\delta-\omega\fallingdotseq1.0997$ [mm]																	
Ⓖ	Primary container lid tie down bolts			280.8	3.09	56.3	283.9	Sy/1.5 =444	0.56	–	–	–	340.2	Sy =666	0.95	1360.8*	680.4	100	1000	0.1	9

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

Table(II)-A.9 Results of Stress Evaluation under Variation of Pressure (3/3)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted \ Stress and stress intensity			Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Evaluation of primary stress intensity						Evaluation of composite stress intensity (primary + secondary)			Fatigue evaluation					
							$P_m(P_L)$	Sm	MS	P_L+P_b	1.5Sm	MS	P_L+P_b+Q	3Sm	MS	P_L+P_b+Q+F	Sa	N	Na	DF	MS
(H)	Center of valve cover	Internal surface	σ_r	—	-15.1(b)	—	0.074	137	1.85×10^3	15.1	206	12.6	15.1	411	26.2	15.1	7.6	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		-15.1(b)																
			σ_z		-0.147																
		External surface	σ_r	—	15.1(b)	—															
			σ_θ		15.1(b)																
			σ_z		0																
(I)	Valve cover tie down bolts			274	1.01	59.2	275	Sy/1.5 =444	0.61	—	—	—	334.2	Sy =666	0.99	1336.8*	668.4	100	1000	0.1	9

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

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Table(II)-A.10 Stress Evaluation Results under the Normal Conditions of Transport (Thermal test) (1/3)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Evaluation of primary stress intensity: Pm(PL)	Sm	MS	PL+Pb	1.5Sm	MS	Evaluation of composite stress intensity (primary + secondary): PL+Pb+Q	3Sm	MS	Fatigue evaluation: PL+Pb+Q+F	Sa	N	Na	DF	MS
Ⓐ	Center of capsule body hull part		σ_r	—	−0.09	—	2.41	137	55.8	—	—	—	2.41	411	169.5	—	—	—	—	—	—
			σ_θ		−2.32																
			σ_z		−1.16																
Ⓑ	Center of capsule body bottom part	Internal surface	σ_r	—	5.77(b)	—	0.086	137	1.59×10^3	5.77	206	34.7	5.77	411	70.3	—	—	—		—	—
			σ_θ		5.77(b)																
			σ_z		0																
		External surface	σ_r	—	−5.77(b)	—															
			σ_θ		−5.77(b)																
			σ_z		−0.172																
Ⓒ	Center of primary container body hull part		σ_r	—	−0.071	—	0.18	137	760.1	—	—	—	4.75	411	85.5	4.75	2.38	100	≥ 10^6	1×10^{-4}	1×10^4
			σ_θ		0.11	4.57															
			σ_z		0.02	4.57															
Ⓓ	Center of primary container body bottom part	Internal surface	σ_r	—	−2.86(b)	—	0.036	137	3.80×10^3	2.86	206	71.0	2.86	411	142	2.86	1.43	100	≥ 10^6	1×10^{-4}	1×10^4
			σ_θ		−2.86(b)																
			σ_z		−0.071																
		External surface	σ_r	—	2.86(b)	—															
			σ_θ		2.86(b)																
			σ_z		0																

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

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Table(II)-A.10 Stress Evaluation Results under the Normal Conditions of Transport (Thermal test) (2/3)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Evaluation of primary stress intensity: $P_m(P_L)$	Sm	MS	P_L+P_b	1.5Sm	MS	Evaluation of composite stress intensity (primary + secondary): P_L+P_b+Q	3Sm	MS	Fatigue evaluation: P_L+P_b+Q+F	Sa	N	Na	DF	MS
Ⓔ	Flange of primary container body	Upper surface	σ_r	—	−0.63(b)	—	—	—	—	0.63	Sy =171	270	0.63	Sy =171	270	0.63	0.32	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		−0.19(b)																
			σ_z		—																
		Lower surface	σ_r	—	0.63(b)	—															
			σ_θ		0.19(b)																
			σ_z		—																
Ⓕ	Center of primary container lid hull part		σ_r	—	−0.04	—	1.03	137	132.0	—	—	—	1.03	411	398	1.03	0.52	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		0.99																
			σ_z		0.49																
Ⓖ	Center of primary container lid upper part		σ_r	—	1.06	—	1.10	137	123.5	—	—	—	1.10	411	372	1.10	0.55	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		1.06																
			σ_z		−0.04																
Ⓗ	Primary container lid flange	Upper surface	σ_r	—	0.99(b)	—	—	—	—	0.99	Sy =171	171.7	0.99	Sy =171	171.7	0.99	0.50	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		0.30(b)																
			σ_z		—																
		Lower surface	σ_r	—	−0.99(b)	—															
			σ_θ		−0.30(b)																
			σ_z		—																

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

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Table(II)-A.10 Stress Evaluation Results under the Normal Conditions of Transport (Thermal test) (3/3)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted (Stress and stress intensity)			Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Evaluation of primary stress intensity						Evaluation of composite stress intensity (primary + secondary)			Fatigue evaluation					
							$P_m(P_L)$	S_m	MS	P_L+P_b	$1.5S_m$	MS	P_L+P_b+Q	$3S_m$	MS	P_L+P_b+Q+F	Sa	N	Na	DF	MS
Ⓗ	Primary container lid inside O-ring displacement			① Displacement $\omega = 1.46\times10^{-4}$ [mm] ② Initial displacement of O-ring $\delta = 1.1$ [mm] * ③ Residual displacement of O-ring $\Delta t = \delta - \omega \fallingdotseq 1.0998$ [mm] *; O-ring cross section diameter: 5.6 mm, O-ring slot depth: 4.5 mm																	
Ⓘ	Primary container lid fastening bolt			280.8	1.49	56.3	282.3	Sy/1.5 =444	0.57	—	—	—	338.6	Sy =666	0.96	1354.4*	677.2	100	1000	0.1	9
Ⓙ	Center of valve cover	Internal surface	σ_r	—	−7.28(b)	—	0.036	137	3.85×10^3	7.28	206	27.2	7.28	411	55.4	7.28	3.64	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		−7.28(b)																
			σ_z		−0.071																
		External surface	σ_r	—	7.28(b)	—															
			σ_θ		7.28(b)																
			σ_z		0																
Ⓚ	Valve cover tie down bolts			274	0.49	59.2	274.5	Sy/1.5 =444	0.61	—	—	—	333.7	Sy =666	0.99	1334.8*	667.4	100	1000	0.1	9

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

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Table(II)-A.11 Stress and Evaluation Results under 1.2 m Bottom End Vertical Drop (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Stress imposed by the impact	Evaluation of primary stress intensity: $P_m(P_L)$	S_m	MS	P_L+P_b	$1.5S_m$	MS	Evaluation of composite stress intensity (primary + secondary): P_L+P_b+Q	$3S_m$	MS	Fatigue evaluation: P_L+P_b+Q+F	Sa	N	Na	DF	MS
Ⓐ	Capsule nozzle		σ_r		0.09		—															
			σ_θ	—	−0.48	—	—	94.4	137	0.45	—	—	—	94.4	411	3.35	—	—	—	—	—	—
			σ_z		−0.24		94.2															
Ⓑ	Center of capsule flange	Upper surface	σ_r		—		−125.7 (b)															
			σ_θ	—	—	—	−37.8 (b)															
			σ_z		—		—	—	—	—	125.7	206	0.63	125.7	411	2.26	—	—	—	—	—	—
		Lower surface	σ_r		—		125.7 (b)															
			σ_θ	—	—	—	37.8 (b)															
			σ_z		—		—															
Ⓒ	Capsule body hull part		σ_r		−0.09		—															
			σ_θ	—	−2.33	—	—	29.5	137	2.64	—	—	—	29.5	411	12.9	—	—	—	—	—	—
			σ_z		−1.16		28.3															
Ⓓ	Center of primary container body hull part		σ_r		−0.071	—	—															
			σ_θ	—	0.11	3.66	—	10.8	137	11.6	—	—	—	10.8	411	37.0	10.8	5.4	100	$\geq 10^6$	1×10^{-4}	1×10^{-4}
			σ_z		0.02	3.66	−10.7															
Ⓔ	Valve cover tie down bolts		σ_b	274	0.49	59.2	8.7 (b)	274.5	Sy/1.5 =444	0.62	283.2	Sy =666	13.5	342.6	Sy =666	0.94	1370*	685	100	1000	0.1	9

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety (b); Bending component *; Stress concentration factor=4

Table(II)-A.12 Stress Evaluation Results under 1.2 m Top End Vertical Drop (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted	Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Stress imposed by the impact	Evaluation of primary stress intensity: $P_m(P_L)$	Sm	MS	P_L+P_b	1.5Sm	MS	Evaluation of composite stress intensity (primary + secondary): P_L+P_b+Q	3Sm	MS	Fatigue evaluation: P_L+P_b+Q+F	Sa	N	Na	DF	MS
(A)	Capsule nozzle	σ_r	–	−0.09	–	–	94.3	137	0.44	–	–	–	94.3	411	3.34	–	–	–	–	–	–
		σ_θ		−0.48		–															
		σ_z		−0.24		−94.2															
(B)	Capsule flange, Upper surface	σ_r	–	–	–	125.7(b)	–	–	–	125.7	206	0.63	125.7	411	2.26	–	–	–	–	–	–
		σ_θ		–		37.8(b)															
		σ_z		–		–															
	Capsule flange, Lower surface	σ_r	–	–	–	−125.7(b)															
		σ_θ		–		−37.8(b)															
		σ_z		–		–															
(C)	Capsule flange fixing bolts		–	–	–	23.9	23.9	Sy/1.5 =444	17.5	–	–	–	23.9	Sy =666	26.8	–	–	–	–	–	–
(D)	Center of capsule body hull part	σ_r	–	0.09	–	–	29.6	137	3.62	–	–	–	29.6	411	12.8	–	–	–	–	–	–
		σ_θ		−2.32		–															
		σ_z		−1.16		−28.3															
(E)	Center of primary container lid hull part	σ_r	–	−0.071	–	–	48.7	137	1.34	–	–	–	48.7	411	7.43	48.7	24.4	100	≥ 10^6	1×10^{-4}	1×10^4
		σ_θ		0.99		–															
		σ_z		0.49		−48.2															
(F)	Center of primary container lid upper part	σ_r	–	1.06	–	−53.5	53.5	137	1.56	–	–	–	53.5	411	6.68	53.5	26.8	100	≥ 10^6	1×10^{-4}	1×10^4
		σ_θ		1.06		−53.5															
		σ_z		−0.04		−1.80															
(G)	Valve cover tie down bolts	σ_b	274	0.49	59.2	8.7(b)	274.5	Sy/1.5 =444	0.62	283.2	Sy =666	1.35	342.4	Sy =666	0.94	1370*	685	100	1000	0.1	9

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Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety (b); Bending component *; Stress concentration factor=4

Table(II)-A.13 Stress Evaluation Results under 1.2 m Horizontal Drop (1/1)

Unit of stress & stress intensity: N/mm²

Symbol	Location where evaluation conducted (Stress and stress intensity)		Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Stress imposed by the impact	Evaluation of primary stress intensity						Evaluation of composite stress intensity (primary + secondary)			Fatigue evaluation					
							$P_m(P_L)$	Sm	MS	P_L+P_b	1.5Sm	MS	P_L+P_b+Q	3Sm	MS	P_L+P_b+Q+F	Sa	N	Na	DF	MS
(A)	Capsule nozzle	σ_r	—	−0.09	—	—	0.39	137	350	104.2	206	0.97	104.2	411	2.94	—	—	—	—	—	—
		σ_θ		−0.48		—															
		σ_z		−0.24		103.9(b)															
		τ		—		2.1															
(B)	Capsule body hull part	σ_r	—	−0.09	—	—	48.0	137	1.84	150.1	206	0.37	150.1	411	1.73	—	—	[illegible]	[illegible]	—	—
		σ_θ		−2.32		−147.9(b)															
		σ_z		−1.16		−46.9															
(C)	Capsule flange fixing bolts	σ_b	—	—	—	252.5(b)	—	—	—	252.5	Sy =666	1.63	252.5	Sy =666	1.63	—	—	—	—	—	—
(D)	Center of primary container body hull part	σ_r	—	−0.071	—	−49.8	50.0	137	1.74	—	—	—	53.6	411	6.66	53.6	26.8	100	≥ 10^6	1×10^{-4}	1×10^4
		σ_θ		0.11	3.66	—															
		σ_z		0.02	3.66	—															
(E)	Primary container lid tie down bolts	σ_b	280.8	1.49	56.3	49.8(b)	282.3	Sy/1.5 =444	0.57	332.0	Sy =666	1.00	388.4	Sy =666	0.71	1553.6*	776.8	100	1000	0.1	9.0
(F)	Primary container lid hull part	σ_r	—	−0.071	—	—	1.06	137	128.0	14.9	206	12.8	14.9	411	26.5	14.9	7.5	100	≥ 10^6	1×10^{-4}	1×10^4
		σ_θ		0.99	—	—															
		σ_z		0.49	—	14.3(b)															

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

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Table(II)-A.14 Stress Evaluation Results under 1.2 m Bottom End Corner Drop (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Stress imposed by the impact: Horizontal component	Stress imposed by the impact: Vertical component	Evaluation of primary stress intensity: $P_m(P_L)$	Sm	MS	P_L+P_b	1.5Sm	MS	Evaluation of composite stress intensity (primary + secondary): P_L+P_b+Q	3Sm	MS	Fatigue evaluation: P_L+P_b+Q+F	Sa	N	Na	DF	MS
Ⓐ	Capsule nozzle		σ_r	—	−0.09	—	—	—	68.6	137	0.99	172.7	206	0.19	172.7	411	1.37	—	—	—	—	—	—
			σ_θ		−0.48		—	—															
			σ_z		−0.24		103.9(b)	68.5															
			τ		—		2.1	—															
Ⓑ	Center of capsule body hull part		σ_r	—	−0.09	—	—	—	18.2	137	6.44	143.3	206	0.43	143.3	411	1.86	—	—	—	—	—	—
			σ_θ		−2.32		−141.1(b)	—															
			σ_z		−1.16		−43.9	26.6															
Ⓒ	Capsule flange	Upper surface	σ_r	—	—	—	—	−127.5(b)	—	—	—	127.5	206	0.61	127.5	411	2.22	—	—	—	[illegible]	—	—
			σ_θ		—		—	−35.7(b)															
			σ_z		—		—	—															
		Lower surface	σ_r	—	—	—	—	127.5(b)															
			σ_θ		—		—	35.7(b)															
			σ_z		—		—	—															
Ⓓ	Center of primary container body hull part		σ_r	—	−0.071	—	−52.6	—	52.8	137	1.59	—	—	—	56.1	411	6.32	56.1	28.1	100	$\geq 10^6$	1×10^{-4}	1×10^4
			σ_θ		0.11	3.36	—	—															
			σ_z		0.02	3.36	—	−10.1															

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

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Table(II)-A.15 Stress Evaluation Results under 1.2 m Top End Corner (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Thermal stress	Stress imposed by the impact: Horizontal component	Stress imposed by the impact: Vertical component	Evaluation of primary stress intensity: $P_m(P_L)$	Sm	MS	P_L+P_b	1.5Sm	MS	Evaluation of composite stress intensity (primary + secondary): P_L+P_b+Q	3Sm	MS	Fatigue evaluation: P_L+P_b+Q+F	Sa	N	Na	DF	MS
(A)	Capsule nozzle		σ_r	—	−0.09	—	—	—	68.7	137	0.99	172.6	206	0.19	172.6	411	1.38	—	—	—	—	—	—
			σ_θ		−0.48		—	—															
			σ_z		−0.24		−103.9(b)	−68.5															
			τ		—		2.1	—															
(B)	Capsule body hull part		σ_r	—	−0.09	—	—	—	71.5	137	0.91	143.3	206	0.43	143.3	411	1.86	—	—	—	—	—	—
			σ_θ		−2.32		−141.1(b)	—															
			σ_z		−1.16		−43.9	−26.6															
(C)	Capsule flange	Upper surface	σ_r	—	—	—	—	127.5(b)	—	—	—	127.5	206	0.61	127.5	411	2.22	—	—	—	—	—	—
			σ_θ		—		—	35.7(b)															
			σ_z		—		—	—															
		Lower surface	σ_r	—	—	—	—	−127.5(b)															
			σ_θ		—		—	−35.7(b)															
			σ_z		—		—	—															
(D)	Capsule flange fixing bolts		σ_b	—	—	—	189.7(b)	21.2(b)	—	—	—	229	Sy=666	1.90	229	Sy=666	1.90	916*	458	100	2000	0.05	19.0
(E)	Primary container lid tie down bolts		σ_b	280.8	1.49	56.3	47.6(b)	33.1(b)	282	Sy/1.5 =444	0.57	363	Sy =666	0.83	419.3	Sy=666	0.58	1677*	839	100	700	0.14	6.1
(F)	Primary container lid hull part		σ_r	—	−0.071	—	—	—	46.1	137	1.97	59.8	206	2.44	59.8	411	5.87	59.8	29.9	100	1000	1×10^{-4}	1×10^{4}
			σ_θ		0.99		—	—															
			σ_z		0.49		−13.7(b)	−45.6															

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4 (b); Bending component

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Table(II)-A.16 Stress Evaluation Results under the Stacking Test

Unit of stress & stress intensity: N/mm^2

Symbol	Stress and stress intensity / Location where evaluation conducted		Stress imposed by initial fastening force	Stress imposed by the internal pressure	Stress imposed by thermal expansion	Stress imposed by loading	Evaluation of primary stress intensity						Evaluation of composite stress intensity (primary + secondary)			Fatigue evaluation					
							$P_m(P_L)$	Sy	MS	P_L+P_b	1.5Sm	MS	P_L+P_b+Q	3Sm	MS	P_L+P_b+Q+F	Sa	N	Na	DF	MS
Ⓐ	Protective container hull part	σ_r		—		—															
		σ_θ	—	—	—	—	3.43	171	48.8	—	—	—	—	—	—	—	—	—	—	—	—
		σ_z		—		3.43															

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress F; Peak stress Sa; Repeated peak stress intensity N; Frequency of uses Na; Allowable frequency of repetition DF; Coefficient of fatigue accumulation Sm; Design stress intensity Sy; Design yield strength Su; Design tensile strength MS; Margin of safety *; Stress concentration factor=4

Table(II)-A.17 Stress Evaluation Results under 9 m Bottom End Vertical Drop (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Stress imposed by the impact	Evaluation of primary stress intensity: Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓐ	Capsule nozzle		σ_r	–	−0.09		158.6	294	0.85	–	–	–
			σ_θ		−0.48							
			σ_z		−0.24	158.4						
Ⓑ	Capsule flange	Upper surface	σ_r	–	–	−274(b)	–	–	–	274	441	0.60
			σ_θ		–	−82.2(b)						
			σ_z		–	–						
		Lower surface	σ_r	–	–	274(b)						
			σ_θ		–	82.2(b)						
			σ_z		–	–						
Ⓒ	Capsule body hull part		σ_r	–	−0.09	–	62.7	294	3.67	–	–	–
			σ_θ		−2.23	–						
			σ_z		−1.16	61.6						
Ⓓ	Center of primary container body hull part	Internal surface	σ_r	–	−0.071	–	23.4	294	11.5	–	–	–
			σ_θ		0.11	–						
			σ_z		0.02	−23.3						
Ⓔ	Valve cover tie down bolts			274	0.49	18.9(b)	274.5	Sy/1.5 =444	0.61	293.4	Sy =666	1.26

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety

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Table(II)-A.18 Stress Evaluation Results under 9 m Top End Vertical Drop (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Stress imposed by the impact	Evaluation of primary stress intensity					
							Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓐ	Capsule nozzle		σ_r	—	−0.09	—	158.3	294	0.85	—	—	—
			σ_θ		−0.48	—						
			σ_z		−0.24	−158.4						
Ⓑ	Capsule flange	Upper surface	σ_r	—	—	274(b)	—	—	—	274	441	0.60
			σ_θ		—	82.6(b)						
			σ_z		—	—						
		Lower surface	σ_r	—	—	−274(b)						
			σ_θ		—	−82.6(b)						
			σ_z		—	—						
Ⓒ	Capsule flange fixing bolts			—	—	52.0	52.0	Sy/1.5 =444	7.53	—		—
Ⓓ	Capsule body hull part		σ_r	—	0.09	—	62.7	294	3.68	—		—
			σ_θ		−2.23	—						
			σ_z		−1.16	−61.6						
Ⓔ	Primary container lid hull part		σ_r	—	−0.071	—	105.4	294	1.78	—	—	—
			σ_θ		0.99	—						
			σ_z		0.49	−104.9						
Ⓕ	Center of primary container lid upper part		σ_r	—	1.06	−116.4	119.2	294	1.46	—	—	
			σ_θ		1.06	−116.4						
			σ_z		−0.04	3.91						
Ⓖ	Valve cover tie down bolts			274	0.49	18.9(b)	274.5	Sy/1.5 =444	0.61	293.4	Sy =666	1.26

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety

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Table(II)-A.19 Stress Evaluation Results under 9 m Horizontal Drop (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted (Stress and stress intensity)		Stress imposed by initial fastening force	Stress imposed by the internal pressure	Stress imposed by the impact	Evaluation of primary stress intensity					
						Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓐ	Capsule nozzle	σ_r	—	−0.09	—	0.39	294	752	104.2	441	3.23
		σ_θ		−0.48	—						
		σ_z		−0.24	103.9(b)						
		τ		—	2.1						
Ⓑ	Capsule body hull part	σ_r	—	0.09	—	68.3	294	3.30	217.6	441	1.02
		σ_θ		−2.32	−215.2(b)						
		σ_z		−1.16	−67.0						
Ⓒ	Capsule flange fixing bolts		—	—	367.2(b)	—	—		367.2	Sy =666	0.81
Ⓓ	Center of primary container body hull part	σ_r	—	−0.071	−64.8	64.9	294	3.53	—	—	—
		σ_θ		0.11	—						
		σ_z		0.02	—						
Ⓔ	Primary container lid tie down bolts		280.8	1.49	72.4(b)	282.3	Sy/1.5 =444	0.57	354.7	Sy =666	0.87
Ⓕ	Primary container lid hull part	σ_r	—	−0.071	—	1.06	294	276.3	21.4	441	19.6
		σ_θ		0.99	—						
		σ_z		0.49	20.8(b)						

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety
(b); bending component

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Table(II)-A.20 Stress Evaluation Results under 9 m Bottom End Corner Drop (1/1)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted	Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Stress imposed by the impact: Horizontal component	Stress imposed by the impact: Vertical component	Evaluation of primary stress intensity: Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓐ	Capsule nozzle	σ_r	–	−0.09	–	–	141.8	294	1.07	245.8	441	0.79
		σ_θ		−0.48	–	–						
		σ_z		−0.24	103.9(b)	141.6						
		τ		–	2.1	–						
Ⓑ	Capsule body hull part	σ_r	–	−0.09	–	–	2.95	294	98.6	183.7	441	1.40
		σ_θ		−2.32	−181.3(b)	–						
		σ_z		−1.16	−56.5	54.8						
Ⓒ	Capsule flange, Upper surface	σ_r	–	–	–	−263(b)	–	–	–	263	441	0.67
		σ_θ		–	–	−73.7(b)						
		σ_z		–	–	–						
	Capsule flange, Lower surface	σ_r	–	–	–	263(b)						
		σ_θ		–	–	73.7(b)						
		σ_z		–	–	–						
Ⓓ	Center of primary container hull part	σ_r	–	−0.071	−63.2	–	63.4	294	3.63	–		–
		σ_θ		0.11	–	–						
		σ_z		0.02	–	−20.9						

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety

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Table(II)-A.21 Stress Evaluation Results under 9 m Top End Corner Drop (1/1)

Unit of stress & stress intensity: N/mm²

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Stress imposed by the impact: Horizontal component	Stress imposed by the impact: Vertical component	Evaluation of primary stress intensity: P_m (P_L)	2/3Su	MS	P_L+P_b	Su	MS
Ⓐ	Capsule nozzle		σ_r	—	−0.09	—	—	141.9	294	1.07	245.9	441	0.79
			σ_θ		−0.48	—	—						
			σ_z		−0.24	−103.9(b)	−141.6						
			τ		—	2.1	—						
Ⓑ	Capsule body hull part		σ_r	—	−0.09	—	—	112.4	294	1.61	183.5	441	1.40
			σ_θ		−2.32	−181.3(b)	—						
			σ_z		−1.16	−56.5	−54.8						
Ⓒ	Capsule flange	Upper surface	σ_r	—	—		263(b)	—	—	—	263	441	0.67
			σ_θ		—		73.7(b)						
			σ_z		—		—						
		Lower surface	σ_r	—	—		−263(b)						
			σ_θ		—		−71.5(b)						
			σ_z		—		—						
Ⓓ	Capsule flange fixing bolts			—	—	278.5(b)	43.4(b)	—	—	—	336.4	Sy=666	0.97
Ⓔ	Primary container lid tie down bolts			280.8	1.49	60.0(b)	68.2(b)	282.3	Sy/1.5 =444	0.57	410.5	Sy =666	0.62
Ⓕ	Center of primary container lid hull part		σ_r	—	−0.071	—	—	94.6	294	2.10	111.8	441	2.94
			σ_θ		0.99	—	—						
			σ_z		0.49	−17.2(b)	−94.1						

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety

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Table (II)-A.22 Evaluation Results of Penetration in Drop Test II

(1) Deformation

No.	Location evaluated	Minimum thickness before deformation [mm]	Deformation in drop test I [mm]	Deformation in drop test II [mm]	Thickness after drop of shock absorber [mm]
a	Top-end of protective container	217	143.1	5.3	68.6
b	Base part of protective container	217	137.3	5.3	74.4
c	Hull part of protective container	117	80.2	5.3	31.5

(2) Deformation strain

No.	Location evaluated	Design criteria	Design criteria values	Analysis results	Margin of safety
a	Top-end of protective container	Deformation strain	40%	3.8%	9.5
b	base part of protective container	Deformation strain	40%	3.8%	9.5
c	Hull part of protective container	Deformation strain	40%	3.8%	9.5

Table(II)-A.23 Stress Evaluation Results under the Accident Conditions of Transport (Thermal test)(1/4)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Evaluation of primary stress intensity: Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓐ	Center of capsule body hull part		σ_r	—	−0.11	2.89	268	91.7	—	—	—
			σ_θ		−3.00						
			σ_z		−1.50						
Ⓑ	Center of capsule body bottom part	Internal surface	σ_r	—	7.44(b)	0.11	268	2435	7.44	402	83.0
			σ_θ		7.44(b)						
			σ_z		0						
		External surface	σ_r	—	−7.44(b)						
			σ_θ		−7.44(b)						
			σ_z		−0.22						

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety
(b); Bending component

Table(II)-A.23 Stress Evaluation Results under the Accident Conditions of Transport (Thermal test)(2/4)

Unit of stress & stress intensity: N/mm^2

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Evaluation of primary stress intensity: Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓒ	Center of primary container body hull part		σ_r	—	−0.12	0.31	268	863.5	—	—	—
			σ_θ		0.19						
			σ_z		0.03						
Ⓓ	Center of primary container body bottom part	Internal surface	σ_r	—	−4.87(b)	0.06	268	4.46×10^3	4.87	402	81.5
			σ_θ		−4.87(b)						
			σ_z		−0.12						
		External surface	σ_r	—	4.87(b)						
			σ_θ		4.87(b)						
			σ_z		0						

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety
(b); Bending component

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Table(II)-A.23 Stress Evaluation Results under the Accident Conditions of Transport (Thermal test)(3/4)

Unit of stress & stress intensity: N/mm²

Symbol	Location where evaluation conducted		Stress and stress intensity	Stress imposed by initial fastening force	Stress imposed by the internal pressure	Evaluation of primary stress intensity					
						Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓔ	Flange of primary container body	Upper surface	σ_r	—	−1.08(b)	—	—	—	1.08	Sy=144	132.3
			σ_θ		−0.32(b)						
			σ_z		—						
		Lower surface	σ_r	—	1.08(b)						
			σ_θ		0.32(b)						
			σ_z		—						
Ⓕ	Center of primary container lid hull part		σ_r	—	−0.06	1.75	268	152.1	—		—
			σ_θ		1.69						
			σ_z		0.85						
Ⓖ	Center of primary container lid upper part		σ_r	—	1.81	1.81	268	189	—	—	—
			σ_θ		1.81						
			σ_z		−0.06						

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety
(b); Bending component

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Table(II)-A.23 Stress Evaluation Results under the Accident Conditions of Transport (Thermal test)(4/4)

Unit of stress & stress intensity: N/mm²

Symbol	Location where evaluation conducted \ Stress and stress intensity			Stress imposed by initial fastening force	Stress imposed by the internal pressure	Evaluation of primary stress intensity					
						Pm (P_L)	2/3Su	MS	P_L+Pb	Su	MS
Ⓗ	Flange of primary container body	Upper surface	σ_r	−	1.70(b)	−	−	−	1.70	Sy =144	83.7
			σ_θ		0.51(b)						
			σ_z		−						
		Lower surface	σ_r	−	−1.70(b)						
			σ_θ		−0.51(b)						
			σ_z		−						
	Primary container lid inside O-ring displacement			① Displacement ② Initial displacement of O-ring ③ Residual displacement of O-ring	ω =2.49×10⁻⁴ [mm] δ =1.1 [mm]* $\Delta t=\delta-\omega\fallingdotseq 1.0997$ [mm]	*; O-ring cross section diameter: 5.6 mm, O-ring slot depth: 4.5 mm					
Ⓘ	Primary container tie down bolts			280.8	2.53	283.5	Sy/1.5 =414	0.46	−	−	−
Ⓙ	Center of valve cover	Internal surface	σ_r	−	−12.4(b)	0.06	268	4.46×10³	12.4	402	31.4
			σ_θ		−12.4(b)						
			σ_z		−0.12						
		External surface	σ_r	−	12.4(b)						
			σ_θ		12.4(b)						
			σ_z		0						
Ⓚ	Valve cover tie down bolts		σ_b	274	0.84	274.8	Sy/1.5 =414	0.50	−	−	−

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety
(b); Bending component

Table(II)-A.24 Stress Evaluation Results under 15 m Depth Immersion Test

Unit of stress & stress intensity: N/mm²

Symbol	Location where evaluation conducted \ Stress and stress intensity			Stress imposed by external pressure	Evaluation of primary stress intensity						Remarks (buckling)
					$P_m(P_L)$	2/3Su	MS	P_L+P_b	Su	MS	
Ⓐ	Center of primary container lid hull part		σ_r	−0.075	2.01	294	145.2	—	—	—	Buckling of primary container lid hull part External pressure: P=0.15MPa·G Allowable external pressure Pe=5.67MPa·G Margin of safety: MS=36.8 Buckling of primary container hull part External pressure: P=0.15MPa·G Allowable external pressure Pe=52.4MPa·G Margin of safety: MS=348.3
			σ_θ	−2.08							
			σ_z	−1.04							
Ⓑ	Center of primary container lid upper part		σ_r	−2.24	2.08	294	135.1	—	—	—	
			σ_θ	−2.24							
			σ_z	−0.08							
Ⓒ	Center of primary container body hull part		σ_r	−0.150	0.09	294	365	—	—	—	
			σ_θ	−0.24							
			σ_z	−0.19							
Ⓓ	Center of primary container body bottom part	Internal surface	σ_r	−6.04(b)	0.075	294	3.19×10^3	6.04	441	72.0	
			σ_θ	−6.04(b)							
			σ_z	−0.150							
		External surface	σ_r	6.04(b)							
			σ_θ	6.04(b)							
			σ_z	0							

Pm; Primary membrane stress P_L: Primary local membrane stress P_b; Primary bending stress Q; Secondary stress Sy; Design yield strength Su; Design tensile strength MS; Margin of safety (b); Bending component

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Appendix

The table shows the contrast JIS(Japan Industrial Standard) with ASME.

The value by JIS

(Type 304)

Temp. (℃)	Sm	Sy	Su
RT	137	206	520
75	137	183	466
100	137	171	441
150	137	155	422
200	129	144	402

unit:MPa

The value by ASME

(Type 304)

Temp. (℃)	Sm	Sy	Su
RT	137 (20)	206 (30)	520 (75)
93	137 (20)	172 (25)	490 (71)
149	138 (20)	155 (22.5)	455 (66)
204	129 (18.7)	143 (20.7)	444 (64.4)

unit:MPa
(ksi)

The value by JIS

(Type 630)

Temp. (℃)	Sm	Sy	Su
RT	311	726	932
75	311	688	847
100	311	666	847
150	311	641	846
200	303	621	826

unit:MPa

The value by ASME

(Type 630)

Temp. (℃)	Sm	Sy	Su
RT	310 (45)	724 (105)	931 (135)
93	310 (45)	670 (97.1)	931 (135)
147	310 (45)	641 (93)	931 (135)
204	302 (43.8)	619 (89.8)	906 (131.4)

unit:MPa
(ksi)

As shown above, the two criteria(JIS and ASME) are almost same.